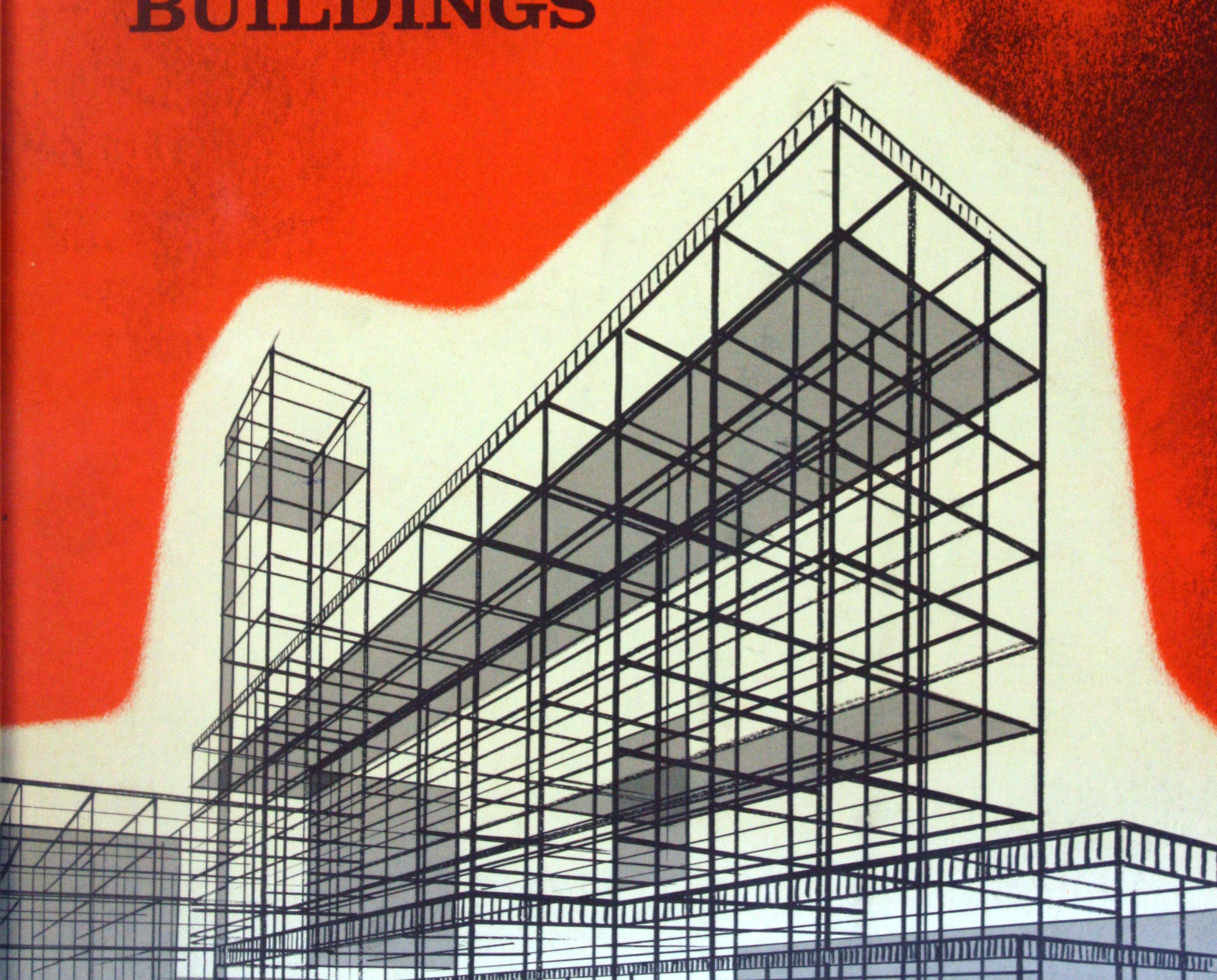
FIRE-RESISTANT CONSTRUCTION IN MODERN STEEL-FRAMED BUILDINGS



Lightweight fireproofing has dramatic influence o

From the time primitive man first settled in communal dwellings of his own construction, uncontrolled fire has been a threat to life and property. In every age civilized man has searched for practical, economical building materials and methods of construction which would best protect his family, his belongings, and his community from the ravages of conflagration.

The search continues today.

(beams)

the design of steel-framed buildings

NO MATERIAL OF CONSTRUCTION has yet been found which can completely resist damage from fire of sufficient intensity or duration. Although structural steel is incombustible and retains its strength to a high degree at temperatures up to 1000° F, the threat of sustained, high-temperature fire, in certain types of constructions and occupancies, requires that the steel frame be protected with fire-resistive insulating materials known as "fireproofing". When so protected, steel-framed buildings are less subject to structural damage from fire than any other known type of construction.

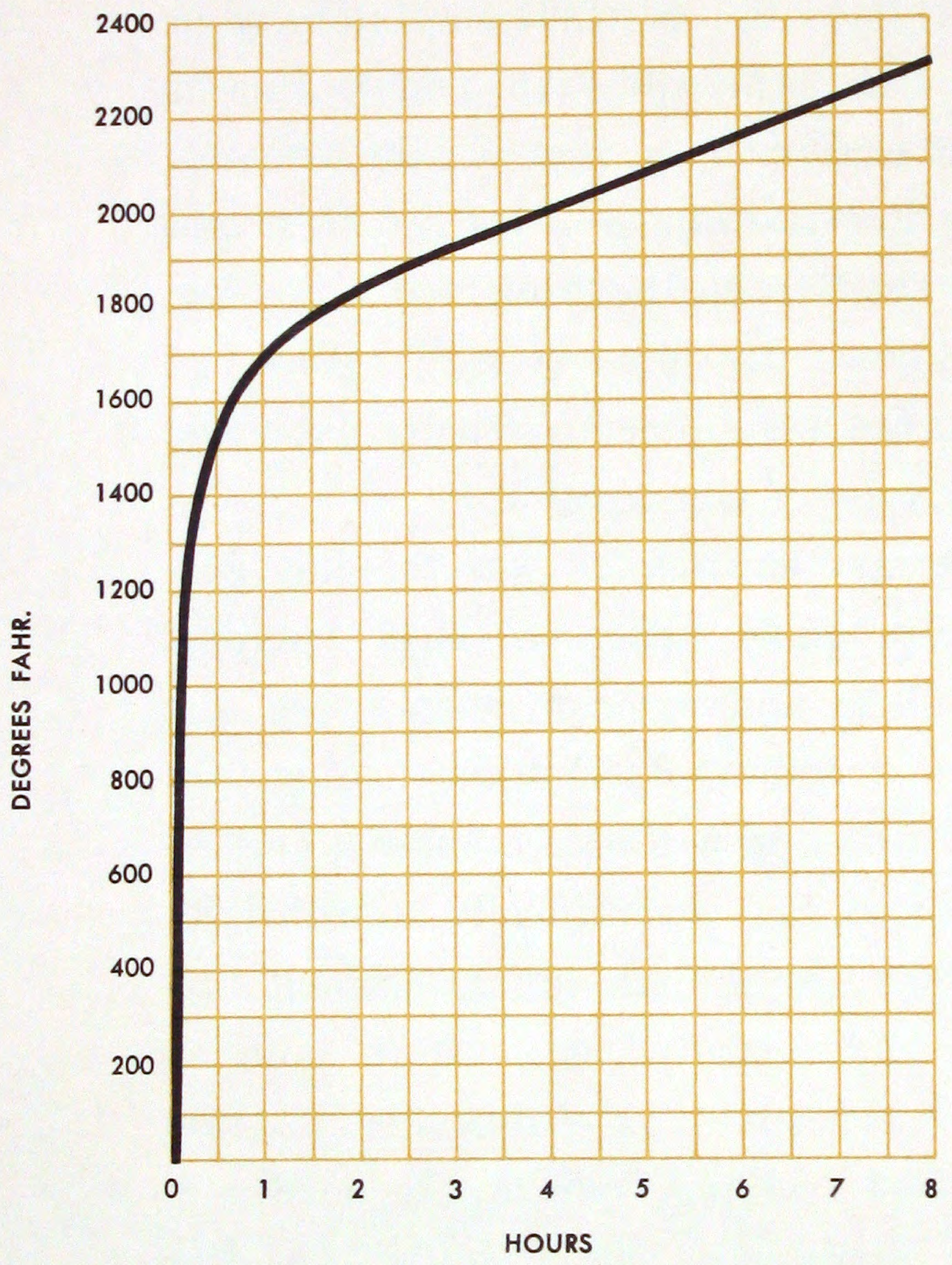
For many years heavy masonry encasement was the only generally accepted method of fireproofing structural steel framing. Usually heavy masonry floor slabs and exterior walls were also required by building codes for construction subject to high fire hazards.

In the past two decades advances in fire protection engineering have resulted in the development of new, scientifically tested, lightweight fireproofing materials. The use of these highly efficient fire-resistive materials, recognized and approved by modern building codes, has made possible a new concept—*light-frame* fire-resistant steel construction. Structural steel framing, free of the burden of heavy masonry fireproofing, is singularly compatible with modern lightweight floors, roofs and walls. These construction components, protected by lightweight fireproofing materials, provide a fire-resistant building outstanding for its flexibility, beauty, economy and safety.

This booklet will review the significant features of the fireproofing materials and fire-resistant constructions which have so dramatically influenced the design of buildings framed in steel, and which hold so much promise for the future. **A reference section** is included to assist the designer in the selection of fire-resistant constructions which will best suit his architectural, economic and building code requirements.

BETTMANN ARCHIVE

All modern building codes require tested fire-resistan



ASTM time-temperature curve shows that in the standard fire test, air temperature rises to 1000° F in only 5 minutes, reaches 1700° F at 1 hour, and 2000° F at 4 hours. Fire resistance ratings based on the ability of assemblies to withstand these temperature conditions assure safe, dependable construction for buildings in which fire hazards make such fire temperatures possible.

MODERN CITIES depend upon building codes to ensure safe, structurally sound construction which will protect life and property from the dangers of uncontrolled fire. These codes must protect the public by maintaining strict regulatory controls over building construction, but must not be so restrictive or inflexible as to prohibit the proper use of new, efficient and economical construction methods or building materials.

Progress in the development of new building materials and methods has resulted in the revision of many building code regulations which were once in force. This is particularly true in the field of fire-resistant construction, where for many years only prescribed constructions of specific materials and thicknesses were acceptable for buildings classified as "fire-resistant" or "fireproof". Materials not listed could not be used, and new products were often automatically excluded. These earlier specified fire-resistant constructions were selected on the basis of estimates and opinions as to their effective fire resistance. It is now evident from physical tests that many of these constructions were considerably over-conservative and costly, while others were unsafe and inadequate to provide the required fire protection.

Modern building codes specify minimum fire resistance requirements based on the scientific studies and techniques of fire protection engineers. The degree of fire hazard in each type and size of construction and for each class of occupancy is scientifically evaluated, and the degree of fire resistance required for each building component is determined in view of the fire hazards involved. The degree of fire resistance required for any structural component is expressed in terms of its ability to withstand fire exposure in accordance with the requirements of the ASTM standard time-temperature fire test.

The standard fire test specification (E 119-58) of the American Society for Testing Materials is the

construction

universally accepted standard for classifying the duration and intensity of fires, and for measuring the degree of fire resistance provided by building materials and constructions. Under this specification, each tested assembly is subjected to a standard fire of controlled extent and severity. The fire resistance rating is expressed as the time, in hours, that the assembly is able to withstand exposure to the standard fire before the first critical point in its behavior is reached. These tests indicate the period of time during which structural members, such as columns and beams, are capable of maintaining their strength and rigidity when subjected to the standard fire. They also establish the period of time during which floors, roofs, walls or partitions will prevent fire spread by protecting against the passage of flame, hot gases and excessive heat.

Most building codes today recognize performance tests as the basis for fire resistance ratings. Minimum ratings are specified in terms of hours, and the fire-resistant value of any building material is not estimated, but is actually measured by means of the ASTM standard fire test. New materials of construction are readily accepted if standard tests prove that they will provide the required degree of fire resistance. Nationally recognized model building codes such as the *Southern Standard Building Code* of the Southern Building Code Congress, the *Uniform Building Code* of the International Conference of Building Officials, the Building Officials Conference of America *Basic Building Code*, and the *National Building Code* of the National Board of Fire Underwriters all recognize performance tests as the basis for fire resistance ratings of construction components.

The fire resistance ratings of the constructions described in this booklet are based on the standard ASTM fire test and can be used with confidence. Architects and engineers can use these tested ratings to design to the actual degree of fire resistance required—with safety, economy, and greater freedom of expression.

Modern fireproofing materials are safe and dependable

Construction materials must meet five basic requirements in order to qualify as safe, dependable fireproofing for steel-framed buildings:

1. They must not burn or support combustion.
2. They must possess sufficient insulating qualities to prevent rapid and excessive flow of heat for a definite period of time.
3. They must be produced in a form which permits economical, flexible application to steel-framed construction.
4. They must be sufficiently standardized and controlled to assure consistent, dependable protection.
5. Their effective fire resistance must be determined by the ASTM standard time-temperature fire test for each type of construction in which they are to be used.

Relatively few materials meet all of these requirements. The materials described below possess each of the characteristics of dependable fireproofing in varying degrees, and are in general use today:

Gypsum is a mineral with unusual fire-resistive qualities. When subjected to high temperatures, gypsum slowly releases water of crystallization in quantities up to one-half its volume. In the presence of fire, this released water is heated to steam, forming an effective thermal barrier. Until the gypsum is completely dehydrated, the side of the insulating layer away from the fire remains relatively cool.

Gypsum plaster, machine or manually applied to metal or gypsum lath, is a popular fireproofing material. Combined with lightweight aggregates, wood fibers or sand, gypsum plaster is used in a wide variety of fire-resistant constructions. Poured or precast gypsum concrete slabs may be used with cellular steel floors, steel deck, and other floor or roof systems. Gypsum wallboard and tile also are components of fire-resistant constructions.

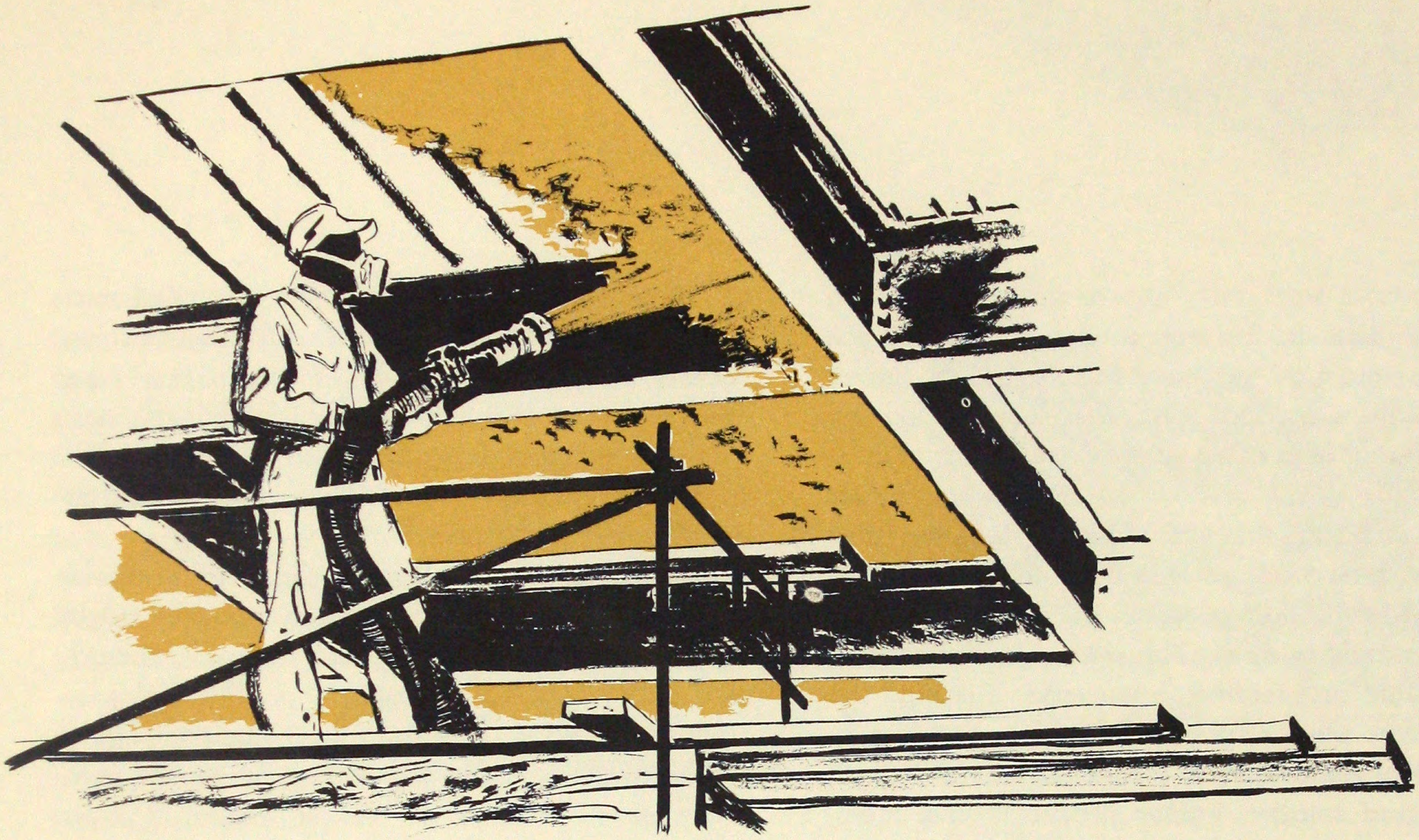
Perlite and vermiculite are lightweight aggregates possessing high thermal insulation qualities. When added to other fireproofing materials, these light aggregates increase effective fire resistance while reducing the dead weight of the fireproofing. These aggregates are used in place of sand in gypsum or cement plaster, and in place of sand and gravel in concrete. They weigh as little as 1/10th the weight of sand.

Vermiculite and perlite are also ingredients in acoustic plaster, sometimes called "acoustical plastic", an acoustical treatment with excellent fire-resistant qualities. Acoustic plaster usually consists of a colloidal clay or gypsum binder, perlite or vermiculite aggregate, mineral fibers, and a foaming agent added to create porosity. The plaster may be machine-applied directly to the underside of light gauge steel floor or roof constructions, to lath, or to a base coat of lightweight gypsum plaster.

Perlite is siliceous volcanic rock that is used in its expanded form. The crude rock is heated to 1800° F, where it "pops" to many times its original volume. The end product resembles small, glass-like bubbles, white in color. Vermiculite is a mineral form of mica. When heated to 2000° F, the mica expands like an accordion, forming multi-celled, lightweight granules of high insulating value.

Mineral fiber is gaining increasing recognition as an efficient lightweight fireproofing material. Incombustible, chemically inert, and a poor conductor of heat, mineral fiber fireproofing also possesses valuable acoustical characteristics.

Sprayed mineral fiber fireproofing is usually applied with a special spray gun which combines the fibers, a mineral binder, air and water, and deposits a blanket of insulation directly to the surface to be protected. Asbestos is the major ingredient in most sprayed fiber fireproofing. This protection will bond directly to the underside of steel floors, metal roof decks, metal lath, and to



most clean, rigid surfaces. It may be used as a lightweight encasement for individual steel framing members. In some constructions an adhesive is applied to the surface of the steel in order to increase the strength of the fiber-to-steel bond.

Acoustic tiles of densely packed mineral fibers, tongued and grooved, and faced with a finish surface coating, have recently been fire-tested and found to have remarkable fire-resistive qualities. This type of compressed fiber fireproofing promises much for the future.

Portland cement concrete continues to be useful as a fireproofing material. In the presence of fire, cement releases water in a manner similar to gypsum, although to a lesser degree. However, due to the high density of cement the vaporized water is sometimes trapped and may build up sufficient internal pressure to spall and weaken the concrete. Similarly, the selection of coarse aggregate is critical to the fire resistance of concrete, since certain minerals contain occluded water which may also cause severe spalling. Although concrete encasement of individual steel framing members is often not an economical construction, concrete encasement of steel columns offers valuable protection against damage by abrasion. When concrete contains vermiculite, perlite, expanded slag, or other light aggregates, it may be used as an efficient lightweight topping over cellular steel floors, in composite floor constructions, or as a slab floor supported by steel joists or junior steel beams.

Portland cement plaster, although less effective in fire resistance than gypsum plaster, may be mixed with vermiculite or perlite aggregates or with sand, and applied in the same manner as gypsum plaster. Usually asbestos or other fiber is added to inhibit spalling. Portland cement plaster is often preferred to gypsum plaster in constructions exposed to weather or unusually high humidity.

Other masonry materials such as brick, hollow clay tile, and cinder blocks are still occasionally used as fireproofing materials under special conditions. For example, brick may be an economical fire protection for spandrel beams in buildings faced with brick. Various masonry column protections offer abrasion resistance or may be selected because of special architectural treatment. In general, however, heavy masonry is no longer in common use as a fireproofing material for structural steel.

Light-frame steel fire-resistant buildings

One of the most outstanding and far reaching developments in the entire field of fire-resistant steel construction has been the increasing use of lightweight structural components protected by lightweight fireproofing materials. Cellular or composite-form floors and roofs, steel joists, junior beams, and light, thin wall elements have replaced older, heavier constructions. Combinations of these elements with other materials of construction such as lightweight concrete, lightweight insulation, and lightweight fireproofing, have made possible the *light-frame* steel structure, in which a minimum amount of dead load is carried by the structural frame, and smaller, lighter structural steel members support the specified design loads.

The development of the *light-frame* steel structure has been in large part due to the parallel development of modern fireproofing materials, and the nationwide acceptance of "performance" type building codes. For many years steel-framed buildings, in order to qualify for the highest fire resistance rating required by building codes, were required to have all exposed parts of each framing member individually encased in heavy masonry enclosures of poured concrete, brick or tile. In addition, various forms of heavy exterior masonry walls, usually of 12-inch minimum thickness, were required. This heavy construction placed a tremendous burden of dead weight on the structural frame of multi-story buildings.

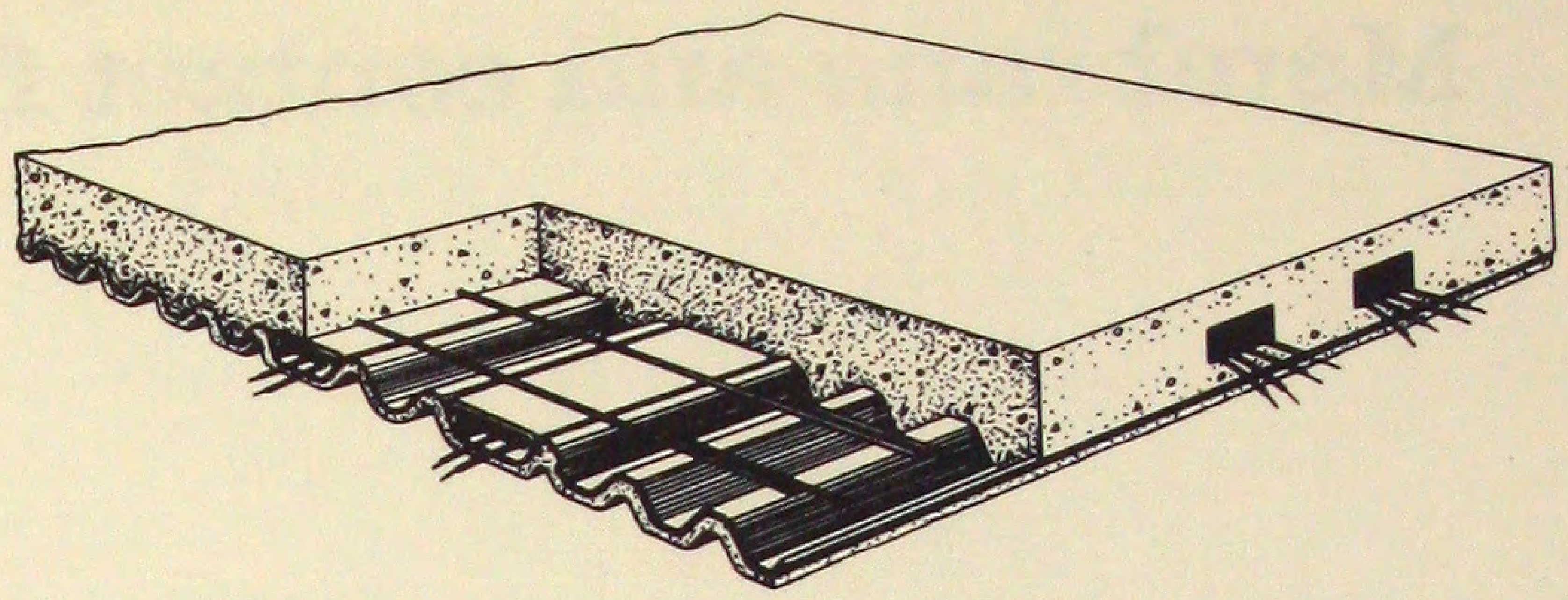
Today, the same fire rating can be achieved by a large and increasing number of lightweight, fire-resistant constructions. Cellular or composite-form floors, or steel joist systems, each supporting a thin concrete slab and protected by lightweight fireproofing, provide fire protection equal to the highest fire resistance requirements of modern building codes. Certain precast concrete cellular floors and composite-form steel floors require no fireproofing to achieve up to 4-hour fire resistance ratings. Curtain walls of stainless steel, aluminum, coated steel, lightweight masonry, and other durable and attractive lightweight wall constructions, usually backed by lightweight fireproofing, also meet code requirements. These light construction elements provide dependable protection with no sacrifice of quality, and with overall economy in the costs of fire-resistant buildings.

These developments have significantly affected the structural steel framework of fire-resistant buildings. In a multi-story steel-framed building, with poured-in-place concrete floor slab and concrete fireproofing, more than fifteen percent of the structural steel may be devoted to carrying its own fireproofing. A single 10 WF 49 column 15 feet high may require 3700 pounds of concrete fireproofing in order to achieve the same 4-hour fire resistance rating as a metal lath and lightweight plaster protection weighing only 500 pounds, or a sprayed mineral fiber covering of less than 200 pounds. Thin-wall construction, protected by lightweight fireproofing, can weigh as little as 12 pounds per square foot of exterior wall area, as contrasted with as much as 150 pounds per square foot for heavy masonry walls. If a lightweight plaster or a sprayed acoustical ceiling were suspended under a 24-foot x 24-foot square floor bay designed for 50 pounds per square foot live load, the elimination of individual concrete fireproofing encasement of the supporting floor beams could reduce the dead load of that bay by more than 35 pounds per square foot or 10½ tons! The use of a cellular or composite-form floor with thin topping could eliminate another 8 tons and result in a total weight saving of 18½ tons for a single bay.

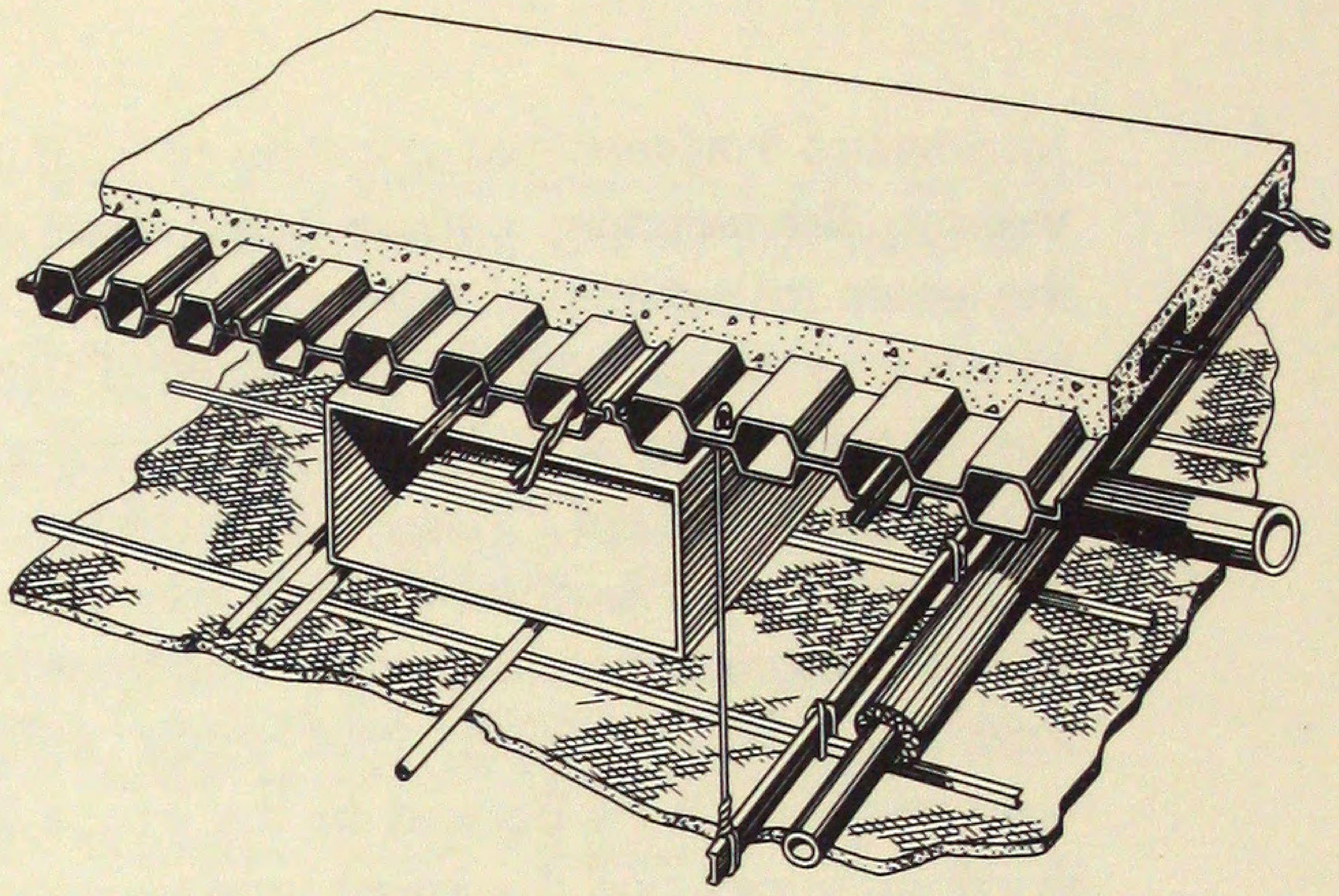
These remarkable weight reductions permit the use of lighter beam, girder and column sections, lighter footings, and substantial savings in the total cost of fire-resistant steel buildings. In a pioneer landmark of *light-frame* fire-resistant steel construction—the 35-story Mercantile Bank Building in Dallas, Texas—the use of vermiculite-gyp-

sum plaster, a cellular steel floor system, and a thin vermiculite concrete slab eliminated a total dead load of 15,634 tons. The resultant saving in structural steel was 1,880 tons or approximately $235,000 at 1941 prices. Since that time, the development and improvement of lightweight structural components and fireproofing materials have achieved significant economies not only through impressive dead load reductions, but also because of the inherent efficiency of such systems.

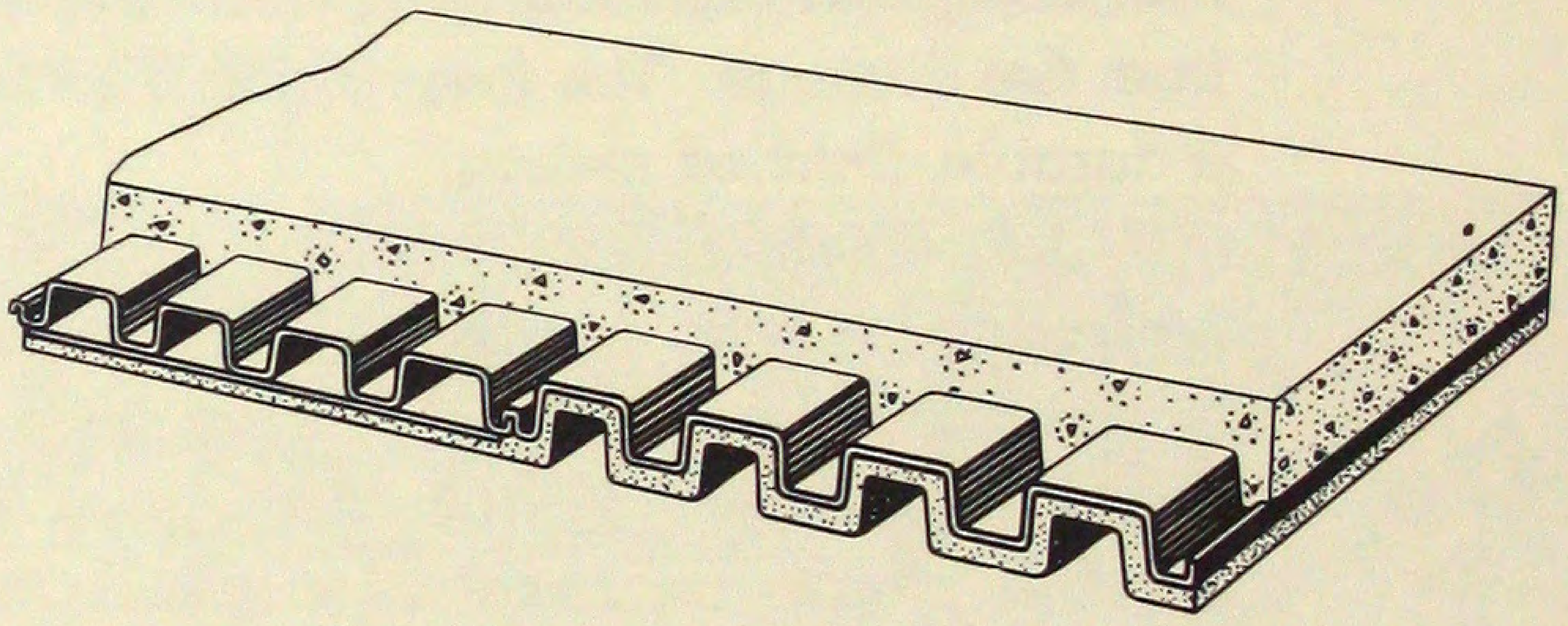
Lightweight fire-resistant constructions offer the designer many advantages in addition to the important economies of dead load reduction. For example, construction time may be considerably reduced when lightweight floor systems are employed. Erection of cellular floors, steel joists and composite-form floors is fast and easy, since the units are light and may quickly be tack-welded to the steel frame. No shoring or formwork interferes with the work of following trades. Lightweight floor systems also permit a high degree of flexibility in the layout and installation of utilities. Cellular floors provide built-in raceways for power, telephone and signal systems for both present and future requirements. Cells may also be used as air conditioning ducts. Composite-form floors may be provided with cellular units to combine the economy of the composite floor with some of the features of the cellular floor. Pipe lines, electrical utilities and air ducts may be easily installed between open-web steel joists as well as through the web openings. When changes in occupancy require extensive alterations, they can be made more easily with these lightweight floor systems than with heavy poured-in-place slabs. Low in cost, flexible in design, practical and economical in the field, and able to effect significant dead load reduction, it is not surprising that lightweight floor systems have achieved universal acceptance in all types of fire-resistant building construction.



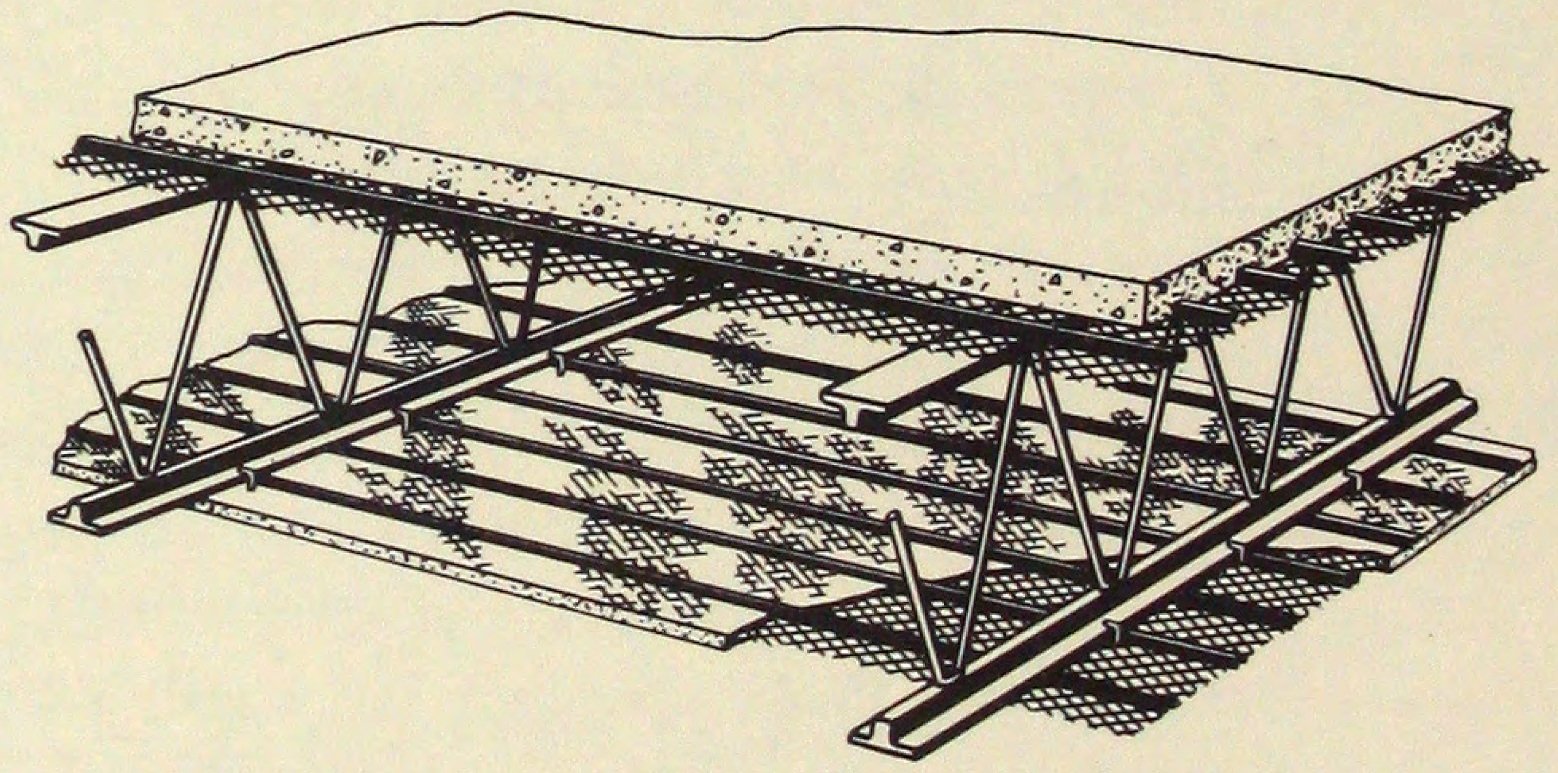
1.



2.



3.



4.

1. Composite-form floor utilizes light gauge steel form as reinforcement for a concrete slab, reducing slab depth and eliminating temporary formwork. Optional cellular units may be utilized to carry electrical circuits.
2. Light gauge cellular floor, topped with concrete fill, is manufactured in several shapes and sizes to suit span and service requirements. Cellular floors provide built-in raceways for electrical service to any part of a building. In some systems large cell panels may be utilized as air carrying ducts, eliminating the need for horizontal ducts below the floor.
3. Cellular floor panels alternated with light gauge steel deck panels provide an economical electrified flooring system.
4. Open-web or solid-web joist systems, topped with thin concrete slabs, are among the most economical of all lightweight floor systems.

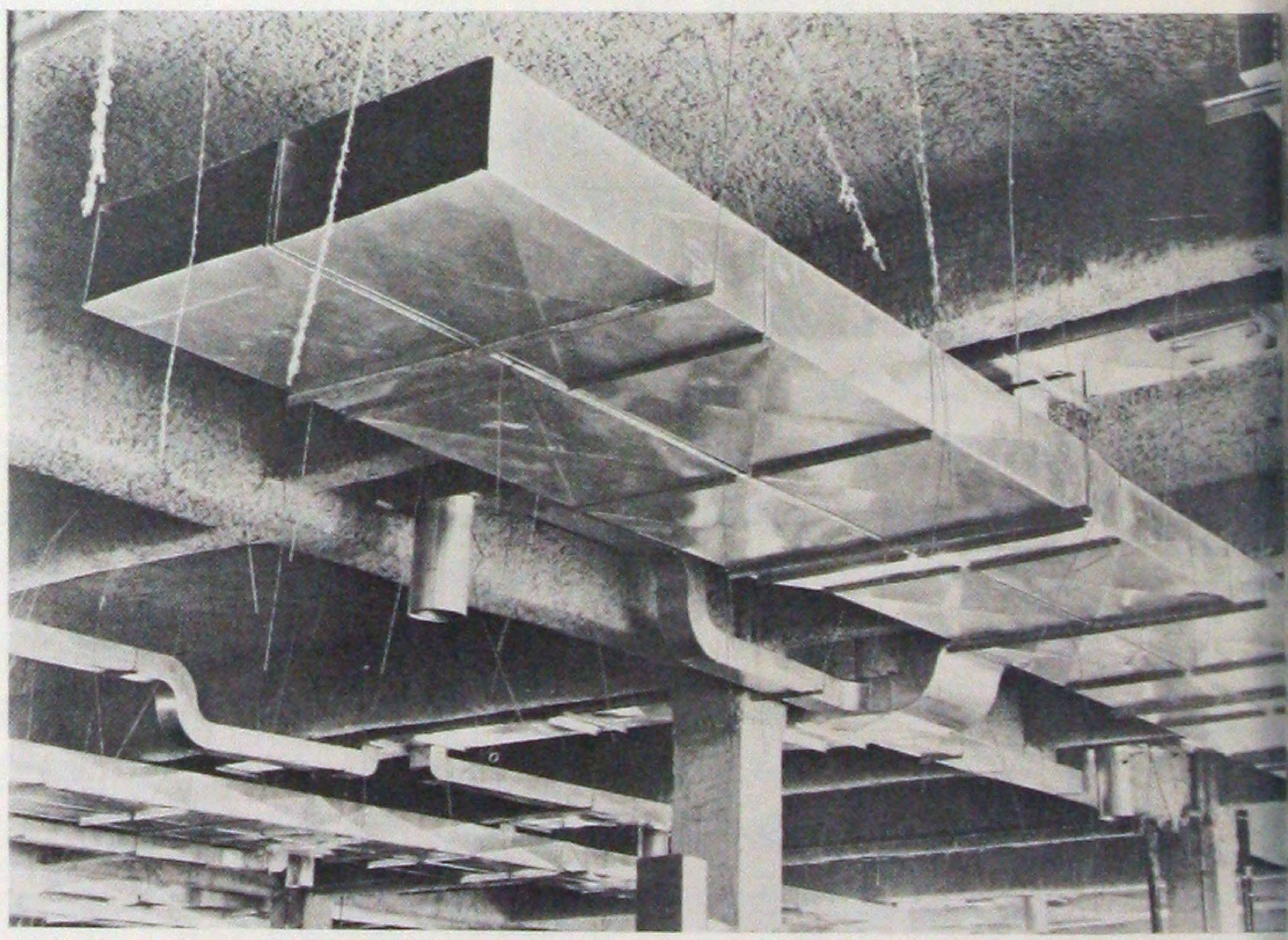
Membrane and contact fireproofing of floors and roofs

MEMBRANE FIREPROOFING consists of a thin, lightweight, fire-resistant ceiling interposed between the potential source of fire and the floor or steel framing to be protected. This form of fire protection can be used with any type of incombustible floor or roof system. It may be furred or directly attached to the bottom flanges of open-web or rolled joists, or suspended below the floor and steel framing. Ducts, piping, and other mechanical equipment may be housed in the space between the floor or roof and the membrane fireproofing below, completely hidden from view and protected from fire damage. The fireproofing also serves as a durable, finished ceiling.

The versatility and economy of membrane fireproofing has been proven in thousands of fire-resistant buildings erected during the past two decades. Ceilings of vermiculite-gypsum or perlite-gypsum plaster on metal or gypsum lath have been employed as fire protection for the floors and framing of all types of steel-framed structures. Recently new materials and new application techniques have improved the efficiency and scope of this lightweight fire protection. Machine application of plaster in many cases has lowered costs and reduced fireproofing time. Tested fire resistance ratings have been established for suspended ceilings pierced for ducts and electric outlets, and have shown that these openings have little effect on fire resistance if their total area is not extensive, and if the duct openings are properly protected with fusible-link dampers. Acoustic plaster, sprayed mineral fiber, and mineral fiber acoustic tiles have been introduced as fireproofing materials which achieve noise reduction as well as fire protection in membrane constructions.

Contact fireproofing is applied directly to the surface of the structural component to be protected. In floor and roof systems, a blanket of acoustic plaster or sprayed mineral fiber is machine-applied directly to the underside of cellular or composite-form steel floors. In some cases lath is attached directly to the underside of the flooring, and lightweight fireproofing materials are applied to the lath, so that the fireproofing material is placed in contact with the floor. With contact fireproofing, the supporting beams and girders must be individually fireproofed in such a manner as to assure continuous protection for the entire floor assembly. When the floor is contact protected by acoustic plaster, the supporting beams are usually wrapped with lath and the plaster is carried around the beam. If sprayed fiber protection is used, the beam may be boxed in a lath and fiber membrane, or the fibers may be sprayed directly to the beam so that a cross-section of the fireproofed beam resembles a bar bell.

This relatively new type of fireproofing has been thoroughly tested, and has achieved wide acceptance in all types and classifications of fire-resistant construction. The popularity of contact fireproofing may be attributed to several significant features of this type of construction. Unless lath is used, only one trade is required for the fireproofing operation. The materials of contact fire-



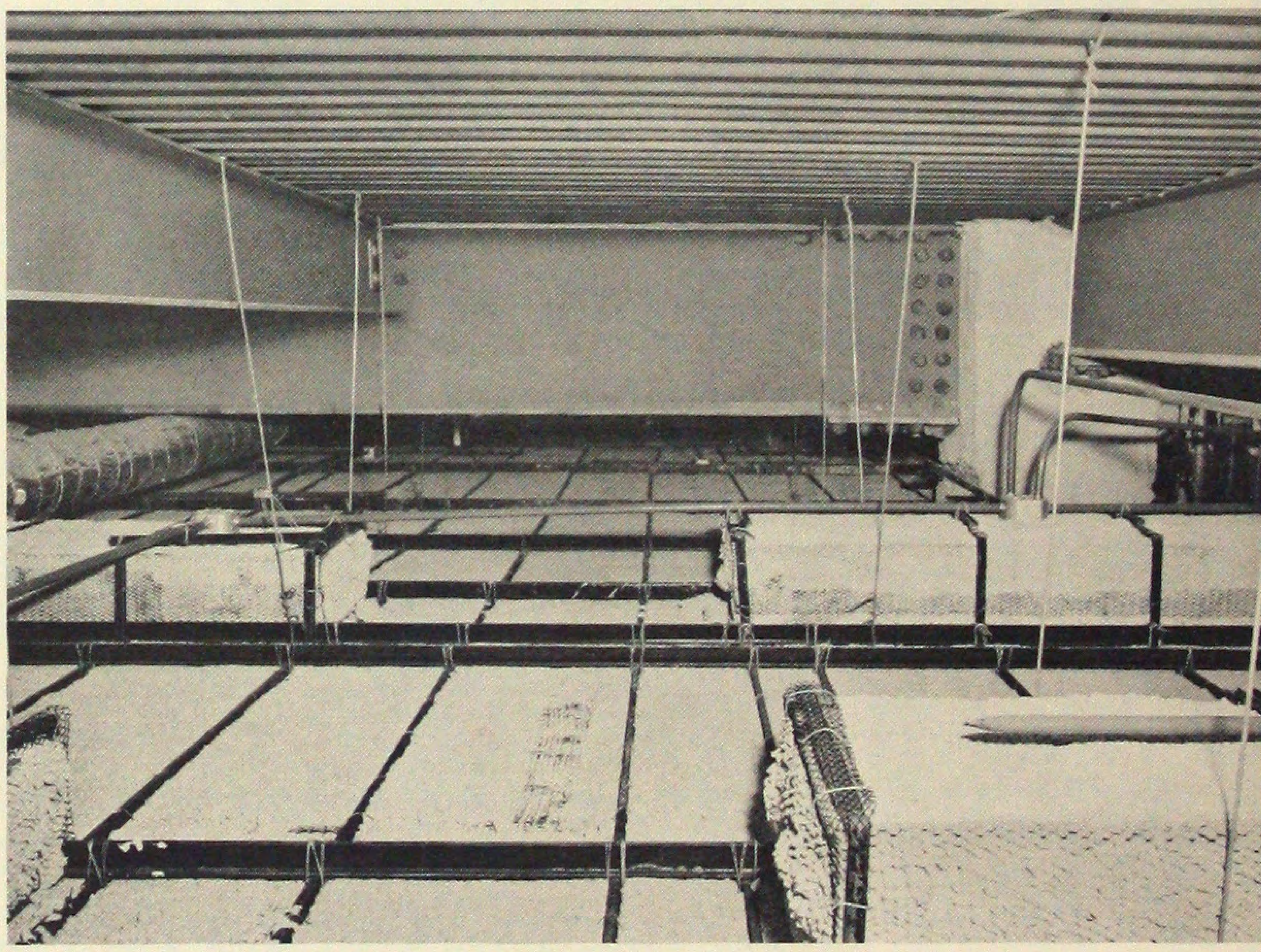
1.

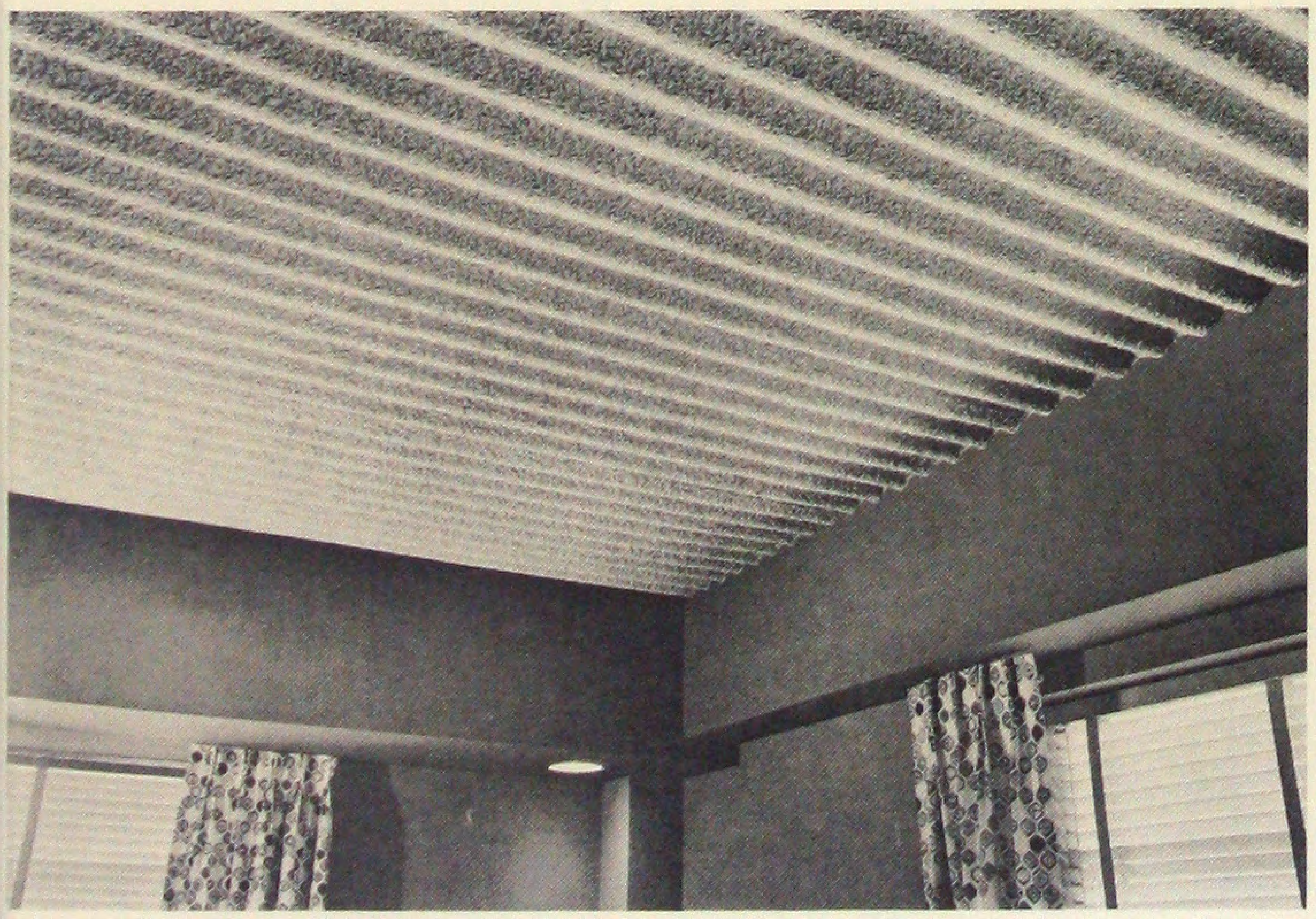
proofing are the lightest of any used for fire protection of steel structures. For these reasons field application is rapid and economical. Both sprayed fibers and acoustic plaster have excellent sound absorption characteristics and may serve a dual function as fire protection and acoustical treatment. Because contact fireproofing is located above all mechanical equipment and ductwork, there is no restriction on the type and size of openings which may be employed in a suspended ceiling. Changes may be made in the location of partitions and lighting fixtures, and mechanical equipment may be altered without disturbing or affecting the contact fireproofing of the floor or steel beams. When used as a finished ceiling, acoustic plaster or sprayed fiber contact fireproofing offers a pleasing, textured appearance.

Both membrane and contact fireproofing are economical, versatile and dependable methods for the fire protection of modern steel-framed building construction. The pages which follow illustrate how each of these fireproofing techniques was employed to meet architectural and code requirements in various types of fire-resistant buildings.

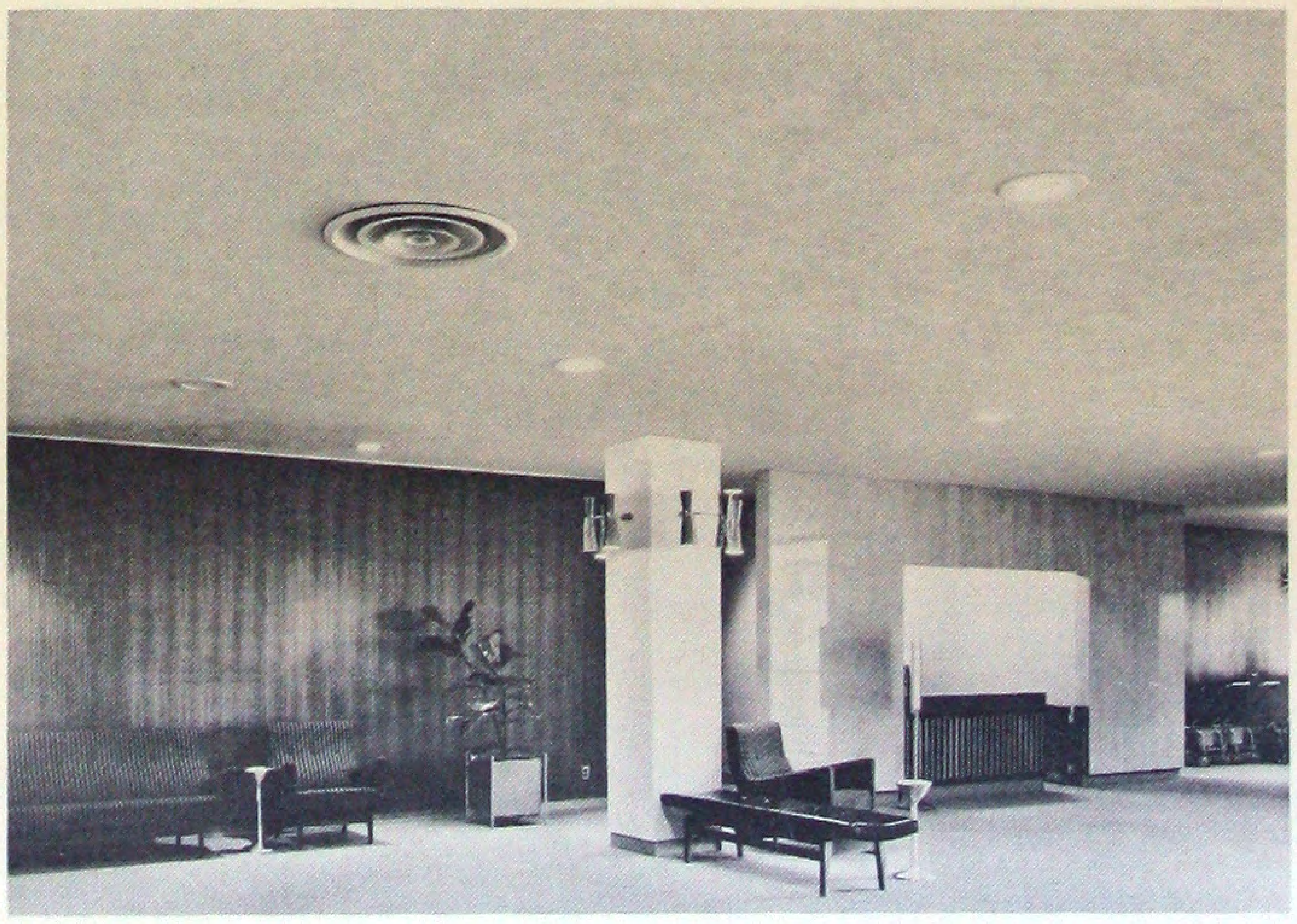
1. Cellular steel floor is contact fireproofed with sprayed mineral fibers. Fibers also are sprayed over metal lath cage to protect steel beams and girders. Note hanger wires which will support a suspended ceiling below the ductwork.
2. Acoustic plaster contact fireproofing on corrugated composite-form floor creates a pleasing textured finish, reduces noise level in this modern hotel room.
3. Membrane lightweight plaster ceiling fire-protects a composite-form floor and steel framing. Plaster fireproofing is carried around the recessed lighting fixtures.
4. Attractive membrane ceiling fire-protects steel framing and floor above. Air conditioning duct opening pierces the fire-resistant ceiling, but does not reduce the effectiveness of the fireproofing.

3.





2.



4.

Federal Department Store survives devastating fire

Building Code: Cleveland, Ohio
Classification: Type 1A—Fireproof
Required Fire Resistance Ratings:
Floors, Roofs, Beams, Girders and Columns: 4 hours
Architect-engineer: Charles N. Agree, Inc., Detroit

In the fall of 1956, lightning struck the Pearl-Brookpark Road branch of the Federal Department Store in Cleveland, Ohio. The disastrous bolt burned its way through the store's electrical system, and fire virtually destroyed the contents of the 128,000 square foot, one-story and basement building. Nine fire companies battled flames for more than eight hours, but the membrane fireproofed steel frame survived the holocaust without damage.

So impressive was the effectiveness of the perlite-gypsum membrane fire protection that architect Charles N. Agree again specified this fire-resistant construction for the remodeled Federal store now in operation.

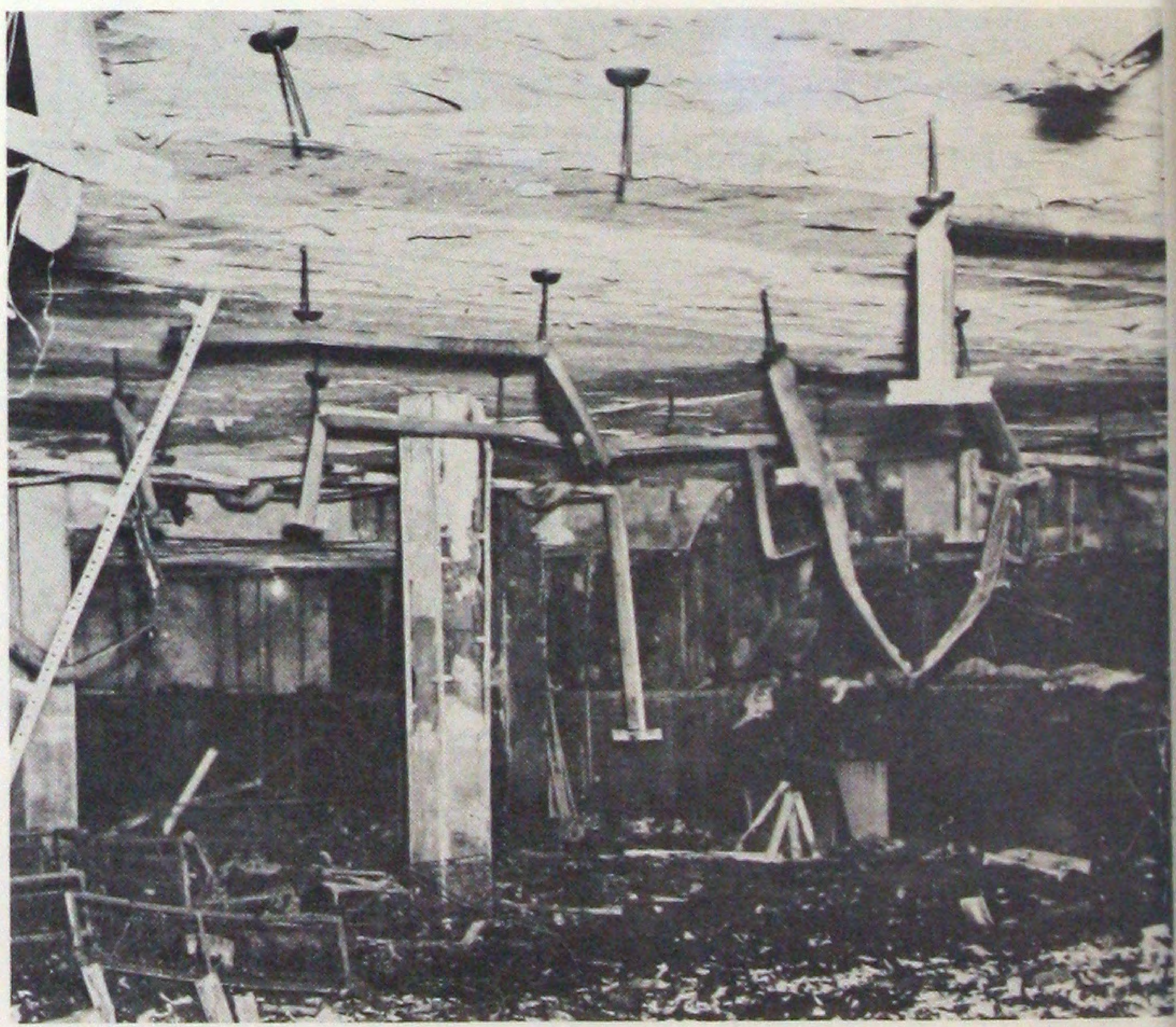
Again protecting the girders and roof trusses is a vast suspended ceiling of 1-inch thick perlite-gypsum plaster on metal lath. Above this membrane protection air-conditioning ducts branch to all sections of the store. Duct openings pierce the fire-resistant ceiling. In the basement area a similar membrane fire-resistant ceiling is attached to the bottom chords of the open-web joists which support a 3-inch concrete first-floor slab. Interior columns are enclosed in plastered gypsum block protection, while columns in contact with the exterior brick walls are brick fireproofed.

Substantial savings in time and money resulted from the ease with which the new fire-resistant ceiling was constructed. All that had to be done to remove the damaged ceilings was to snip the tie wires which suspended them from the floor and roof structures. After modifications were made to the air conditioning and electrical systems, new tie wires and metal lath were attached to the steel framing. Plaster was then machine-applied and the new ceilings were completed in record time.

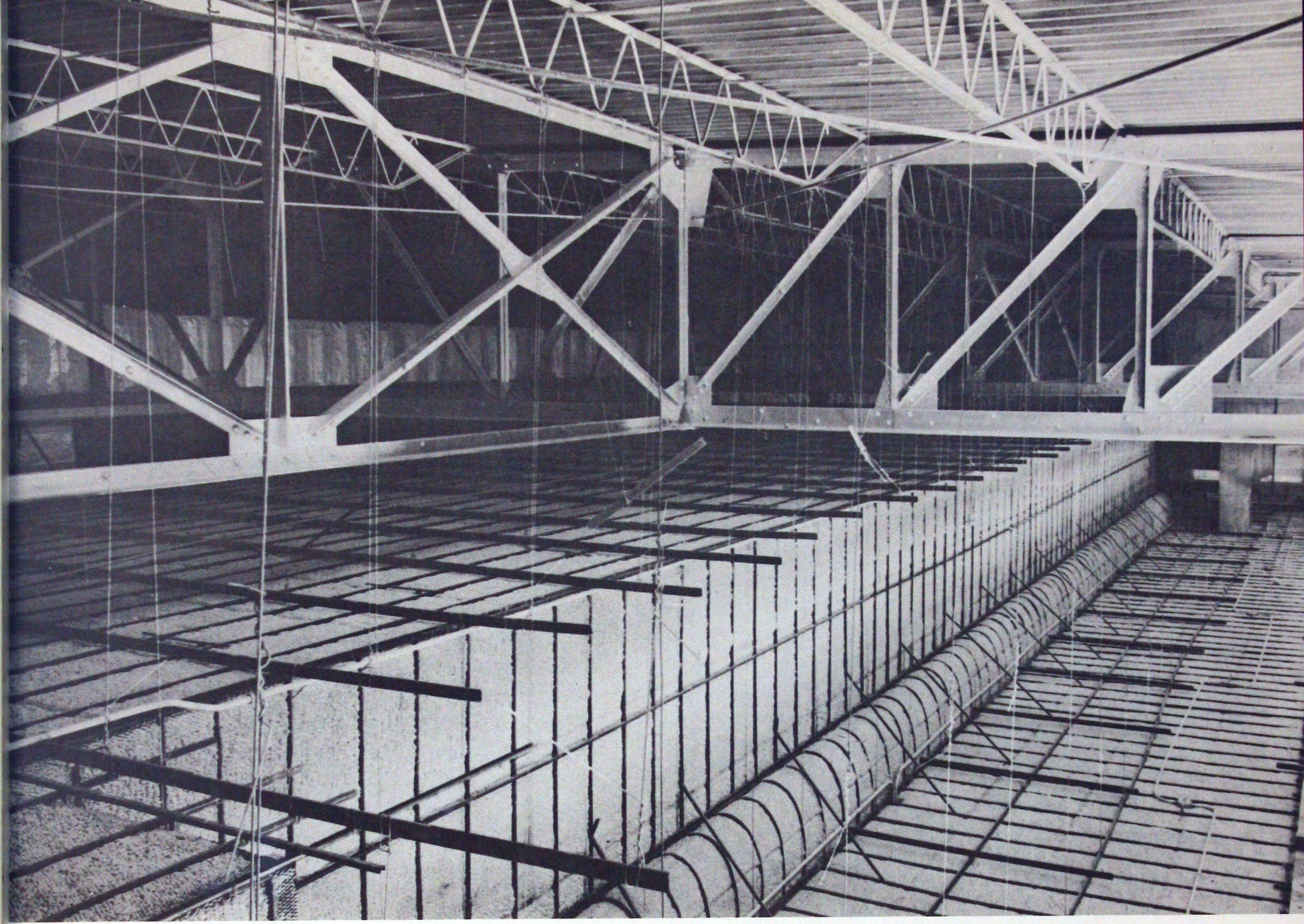
The Federal store fire points up the effective and efficient fire resistance of *light-frame* steel structures protected with lightweight fireproofing, when designed in accordance with the fire resistance requirements of modern building codes.

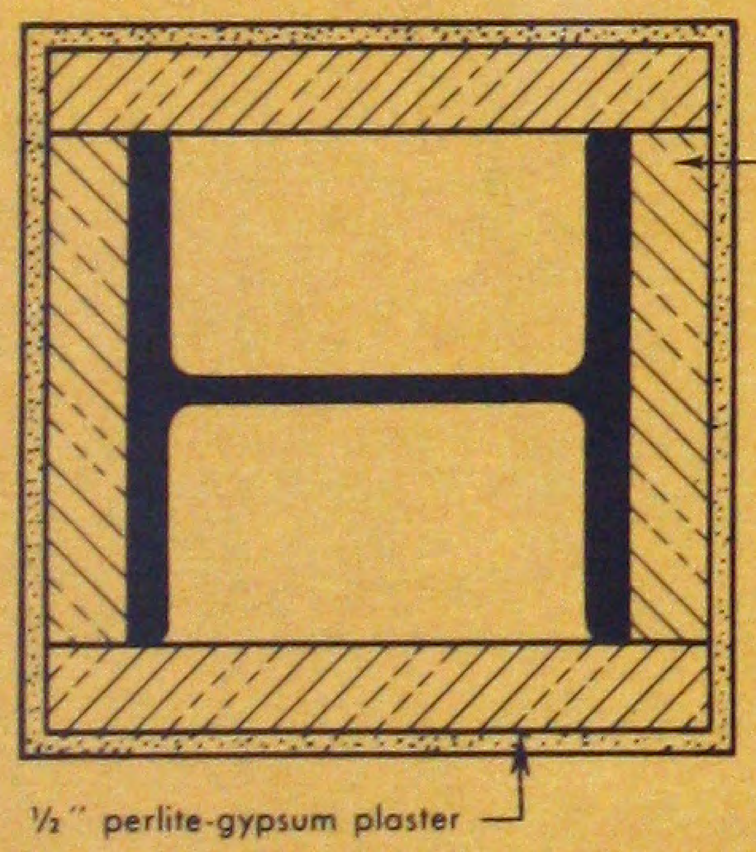
Federal Department Store, located at Pearl and Brookpark Roads, Cleveland, Ohio, survived devastating fire without structural damage.

Suspended membrane fireproofing below the truss and joist framing again protects the roof construction in the remodeled Federal Store.

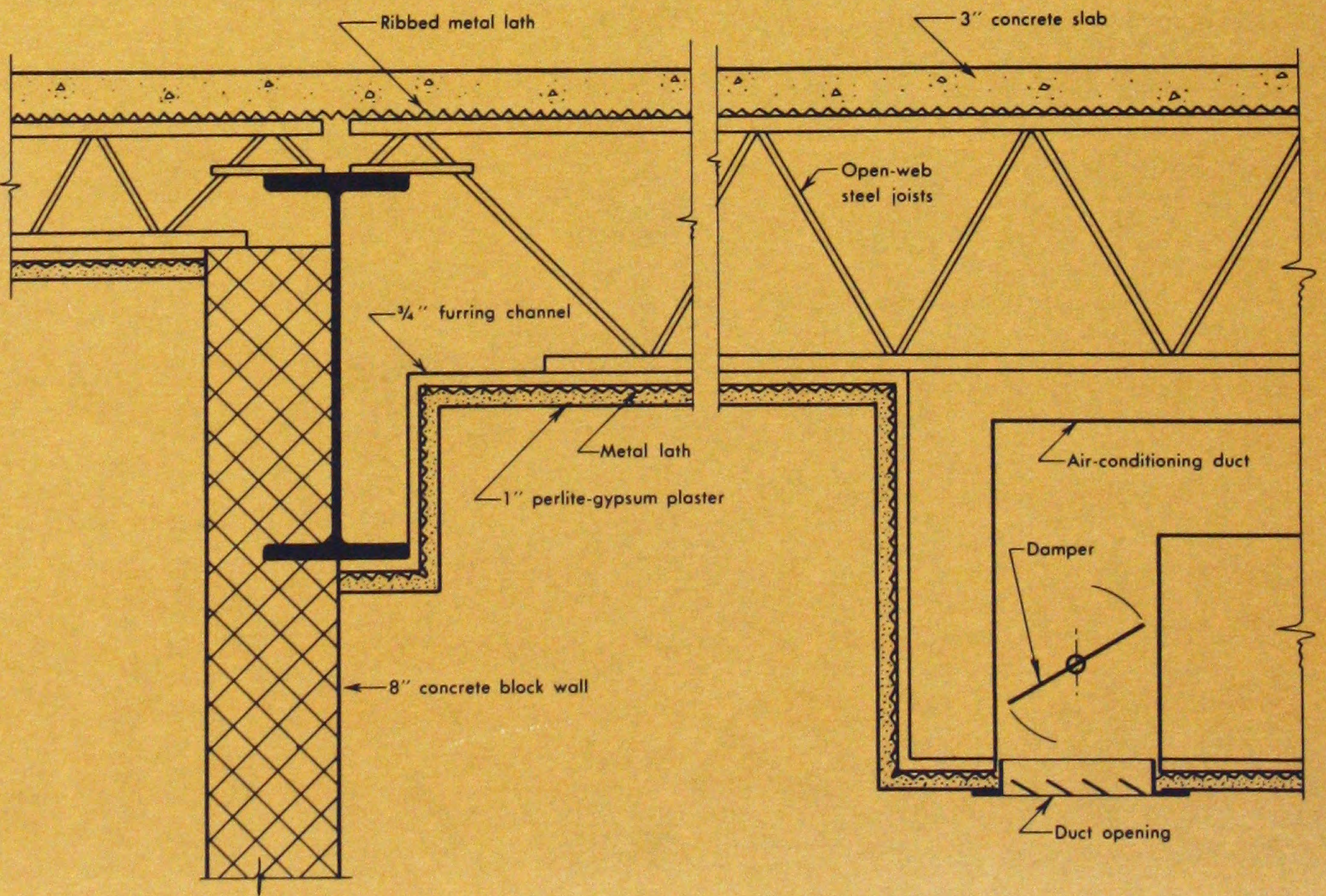


Basement area where membrane ceiling of perlite-gypsum plaster on metal lath successfully protected the structural frame.





Typical interior column in sales area. 4 inches of masonry was specified as fireproofing for exterior and other interior columns.



Typical first floor construction is a thin concrete slab on open-web steel joists, fire-protected by a membrane ceiling. In areas where ductwork is carried below the joists, the ceiling is suspended below the ducts, and openings are provided in the fireproofing.

New York's Union Carbide Building incorporates new

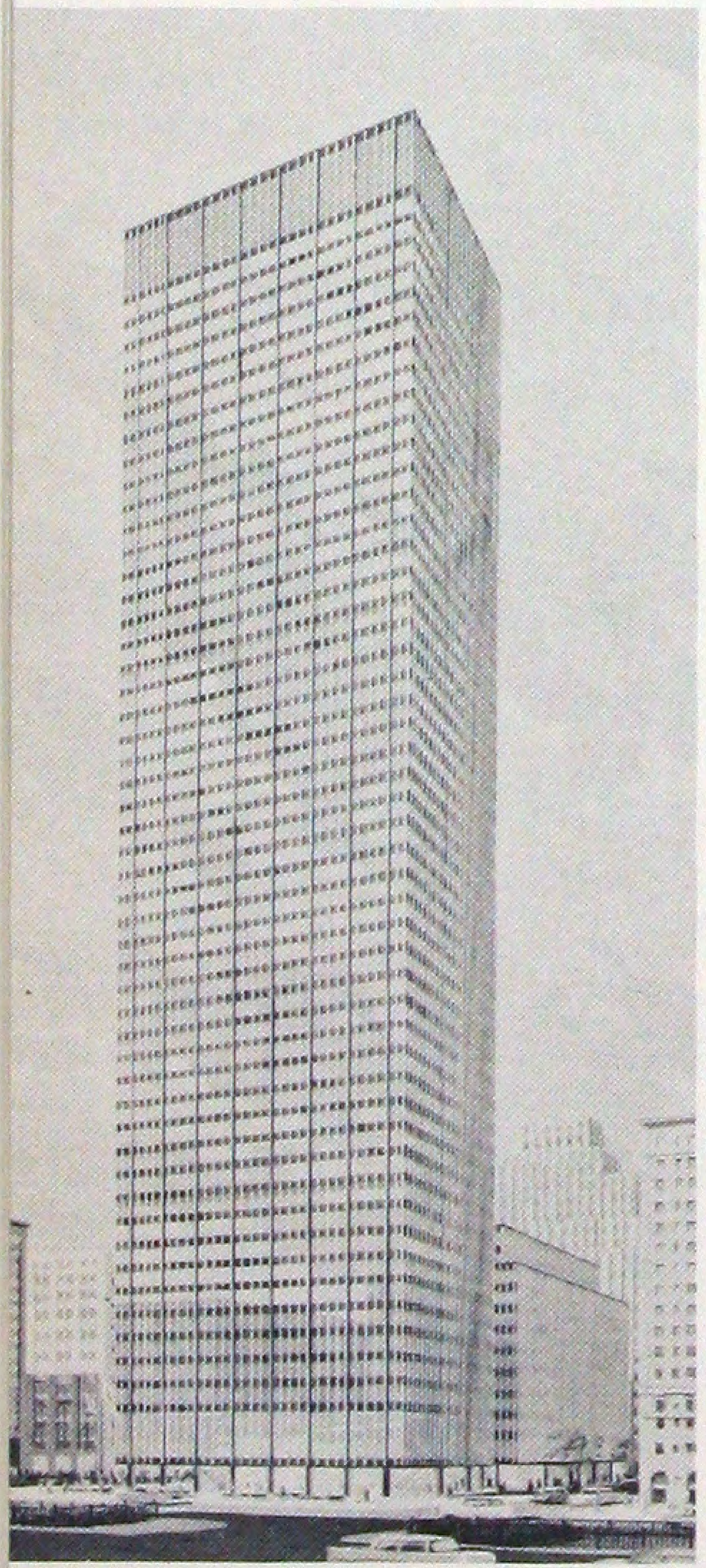
Building Code: Administrative Code of City of New York
Classification: Commercial, Class I—Fireproof
Required Fire Resistance Ratings:
    Columns: 4 hours
    Floors, Roofs, Beams and Girders: 3 hours
Architect: Skidmore, Owings and Merrill
Structural Engineer: Weiskopf and Pickworth, New York

Dominating the skyline of New York's famed Park Avenue is the magnificent new 52-story skyscraper which houses the international headquarters of the Union Carbide Corporation. Standing astride an intricate 2-level railroad track system which serves Grand Central Station, this steel-framed giant towers 720 feet above the city's streets, yet contains less tonnage of steel framing than many of the smaller, older buildings in its shadow. The key to this economy is the use of lightweight construction protected by lightweight fireproofing.

Rarely have the advantages and economies of various fire-resistant constructions been more thoroughly studied and compared than in the design of this multi-million dollar office building. The architectural firm of Skidmore, Owings and Merrill and consulting structural engineers Weiskopf and Pickworth worked closely in selecting the types of construction and fireproofing which would best satisfy their economic, architectural, structural and fire-protective requirements. As a result of their investigations both the new and the old in fire-resistant construction were included in the design.

All of the 47 office floors are constructed of 2½-inch concrete topping on 3-inch deep light-gauge cellular steel decking. A blanket of mineral fiber fireproofing, sprayed directly to the underside of the cellular floor, provides 3-hour fire protection for the floor. Steel beams supporting the cellular floors are protected with a cage of vermiculite-gypsum plaster on metal lath.

Although lightweight fireproofing protects most of the structural framework, the designers specified heavier fire-resistant construction wherever such protection was considered more suitable or economical. For example, all exterior columns and the outside face of all spandrel beams are con-

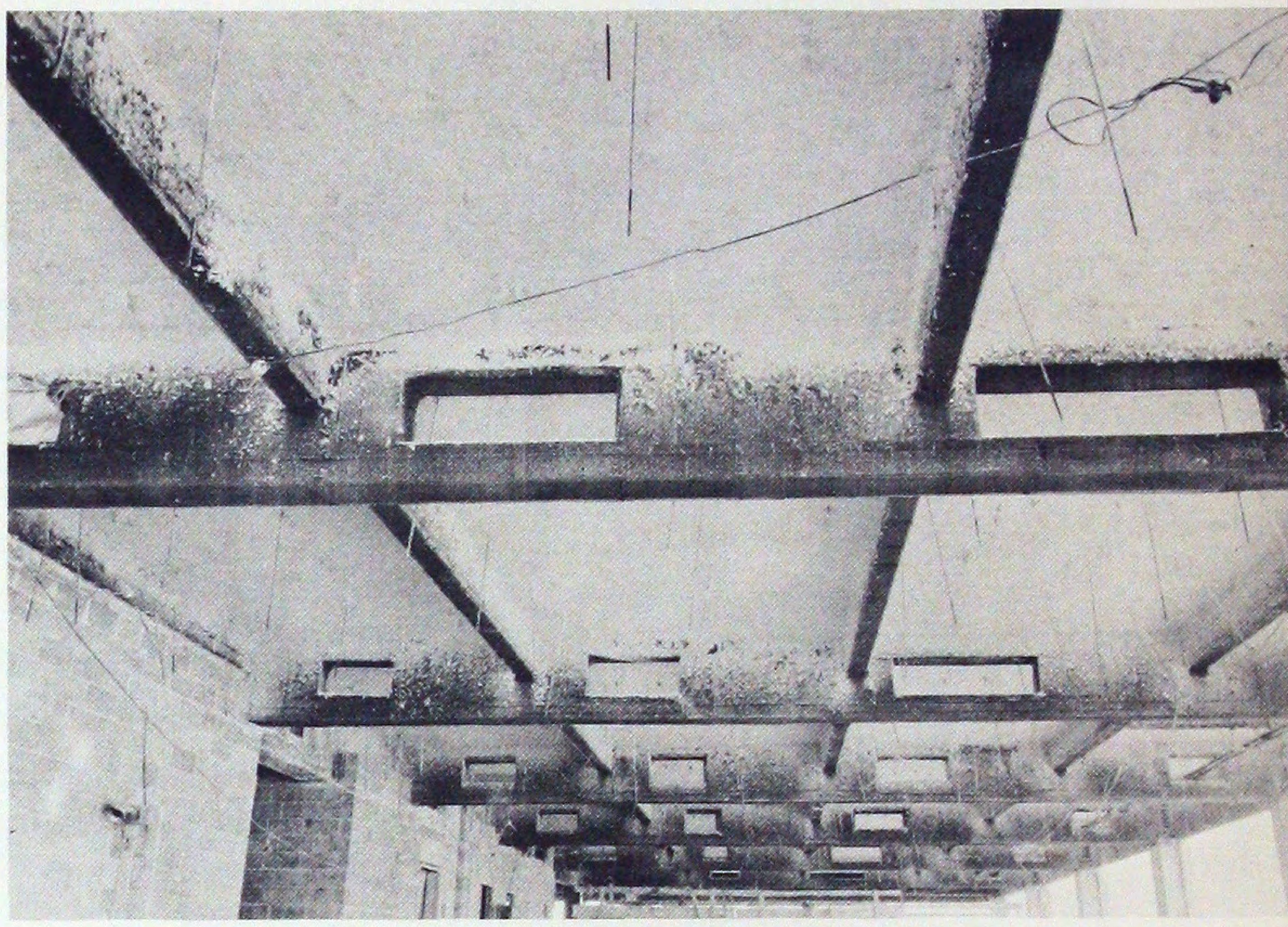


New York's newest landmark, the Union Carbide Building, combines several types of fire-resistant construction. Light curtain walls, cellular steel floors and lightweight fireproofing contribute to dead load reduction. Light gauge cellular steel floor panels provided built-in electrical raceways, and a quick, safe platform on which various craftsmen could work. More than 900,000 square feet of cellular floor was required.

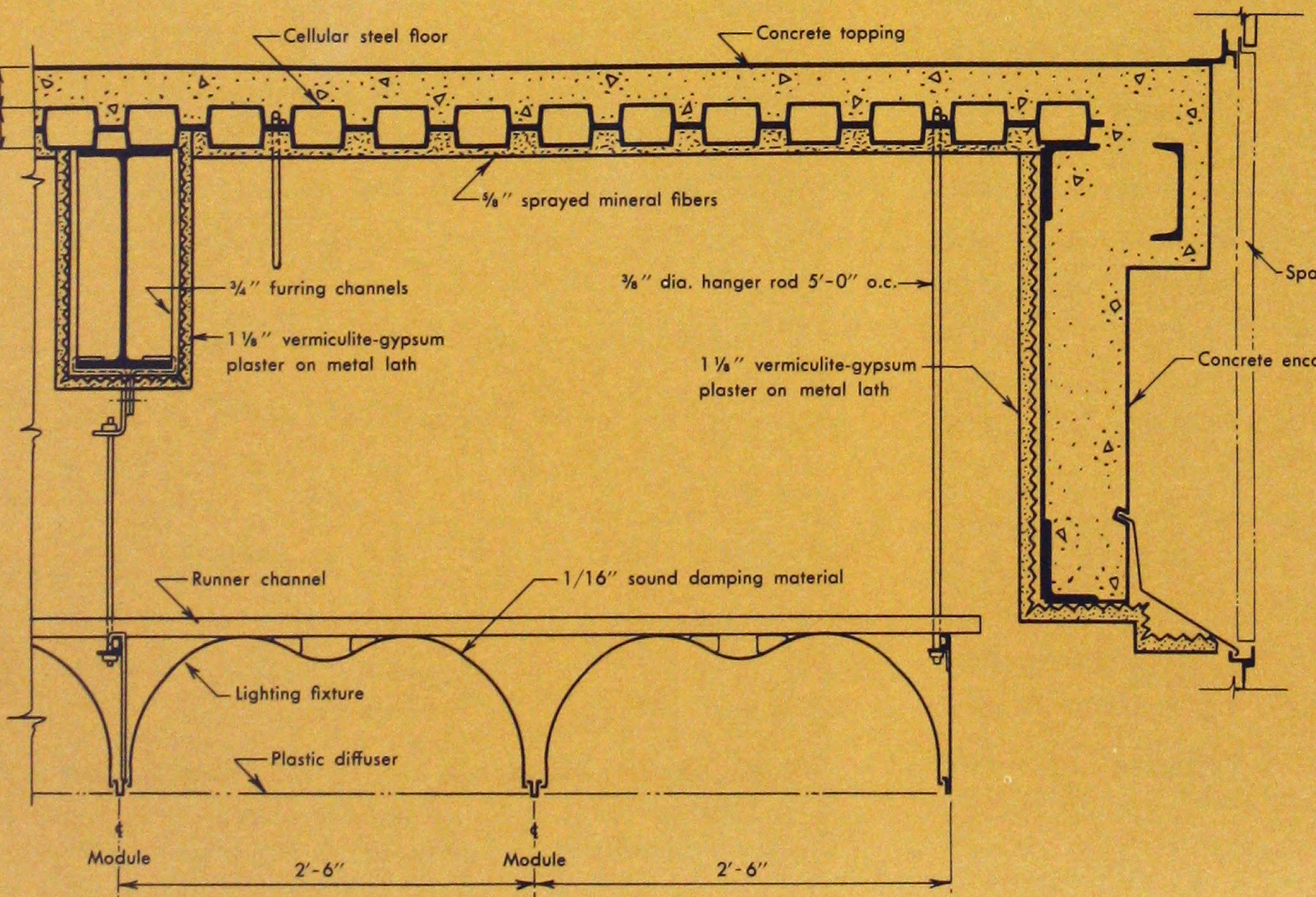
and old in fire-resistant construction

crete encased. Encasement was considered the most economical way to fireproof around the many clips and fittings which hold the curtain walls and miscellaneous iron work to the steel frame. At the lower level, where columns are enclosed in a shell of stainless steel, concrete fireproofing was specified as the most practical method for supporting the thin metal covers. Typical column fireproofing in the office areas is a 3-inch cinder concrete block enclosure faced with 1-inch of sand-gypsum plaster.

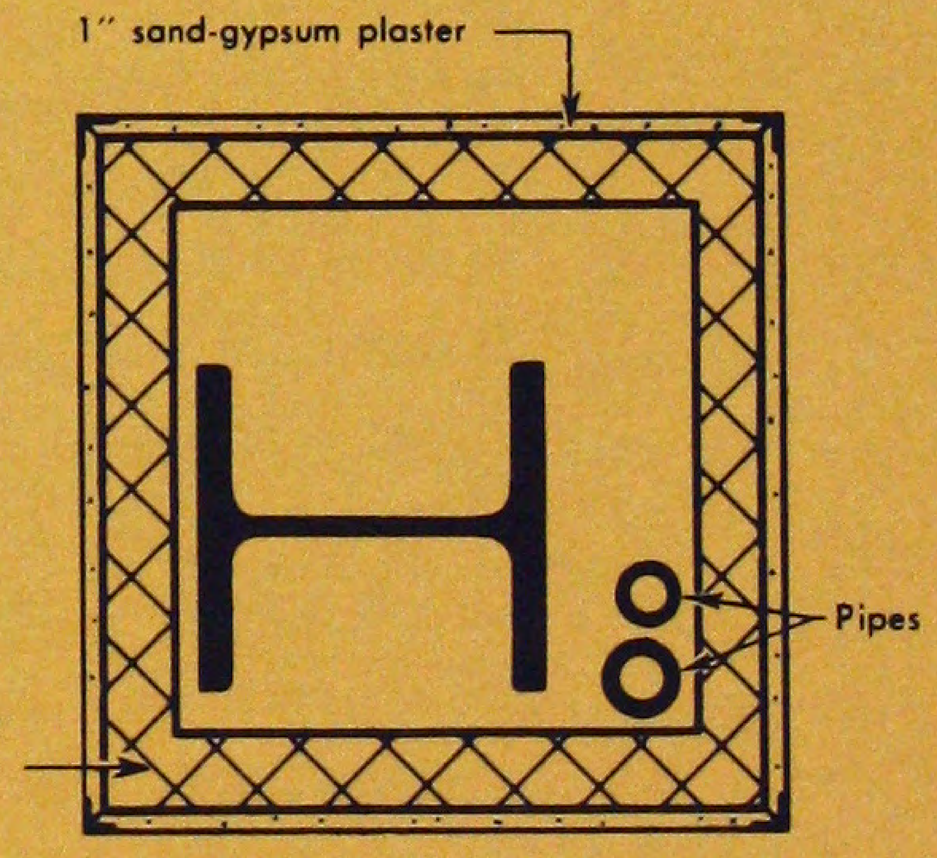
All steel members below the street level are encased in 3000-pound stone concrete. This high grade concrete, not normally used as fireproofing, was specified because of the unusual abuse to which this protection is subjected from railroad operations and maintenance workers. Where forms for poured-in-place concrete could not be placed around steel members, gunite was pneumatically applied as a fire-resistant protection.



Progress photo shows lightweight mineral fibers covering the underside of the cellular floor to meet New York City's 3-hour rating requirement. Steel beams are wrapped in metal lath, will be enclosed with lightweight plaster. Ducts will pass through the cutouts in the beam webs.



Illuminated plastic ceilings are suspended beneath the cellular floor, screening the ductwork and lighting fixtures in the plenum chamber. The lighting reflectors serve as acoustic baffles, and the fiber contact fireproofing completes the acoustical treatment.



Typical interior column fireproofing in the office areas is cinder concrete block enclosure. Plaster is not required to achieve fire resistance rating. Size of enclosure is standardized to maintain a 5 ft. modular pattern. Columns in service core are concrete encased.

High fire resistance with minimum fireproofing

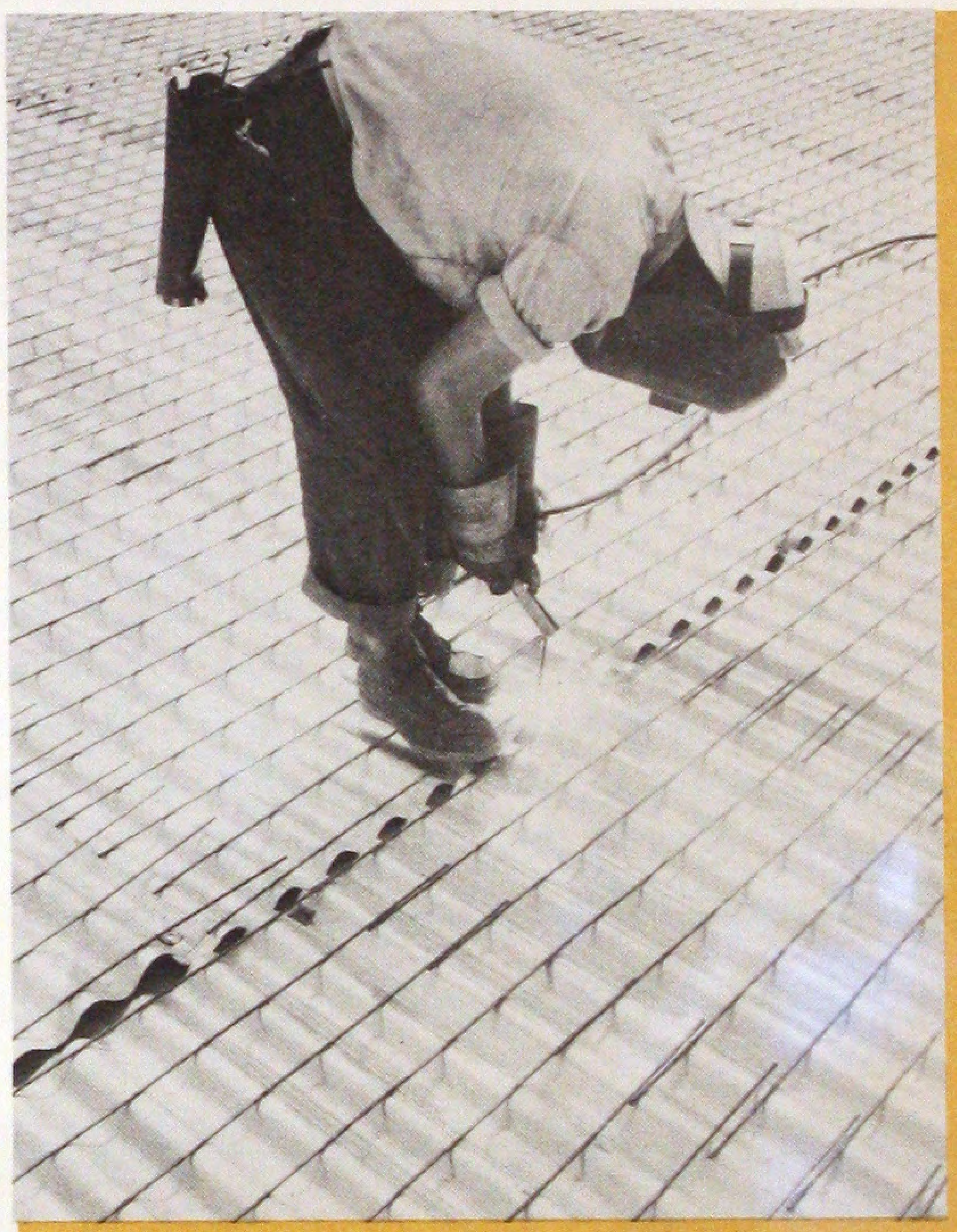
Building Code: St. Paul, Minnesota
Classification: Fireproof—Institutional
Fire Resistance Ratings:
Columns: 4 hours
Floors, Roofs, Beams and Girders: 3 hours
Architect-engineer: Magney, Setter, Leach, Lindstrom & Erickson, Inc., Minneapolis

An outstanding example of efficient, economical lightweight fire-resistant design and construction is the new Bethesda Lutheran Infirmary in St. Paul, Minnesota. Because of the institutional nature of this building, the St. Paul building code required a high fire resistance rating for all structural components. Architects-engineers Magney, Setter, Leach, Lindstrom and Erickson of Minneapolis specified a lightweight composite-form floor system on structural steel framing to achieve full fire safety with a minimum of fireproofing cost.

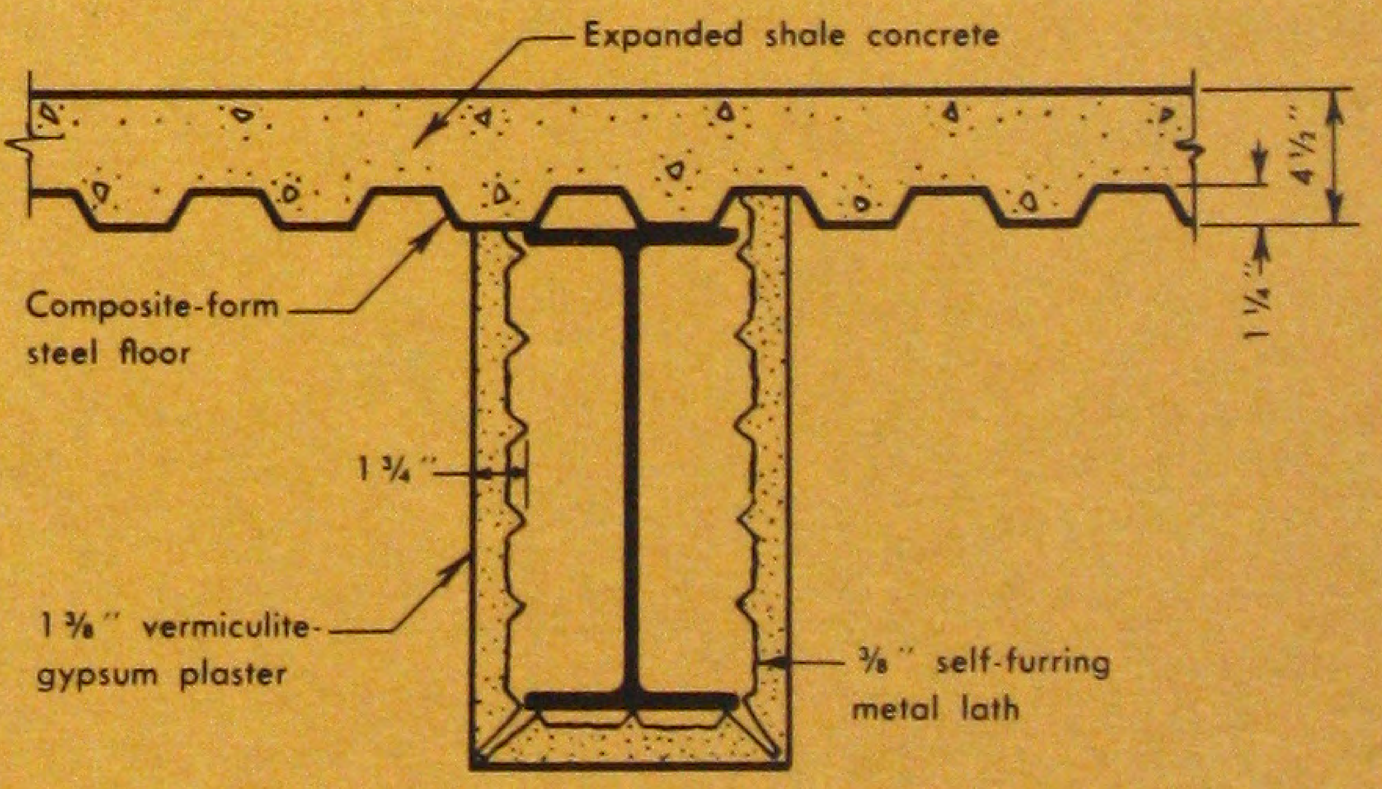
This 100-foot x 100-foot, 4-story and basement building serves 138 aged, infirm patients. The *light-frame* steel structure is designed to permit a future addition of two floors, so that 72 more patients can be accommodated. All patients' rooms are located along the outside walls, and service facilities are housed in a central core.

Typical floor construction is a 4½-inch deep expanded shale concrete composite-form slab welded to steel beams spaced 12 feet on center. Column bays are 24-foot x 24-foot. The designers specified a corrugated composite-form system with transverse temperature rods welded to the galvanized steel form. This type of floor system has less weight and thickness than equivalent conventional reinforced concrete slab construction because the sheet steel form also acts as the primary reinforcement. Dead weight of the slab is only 38 pounds per square foot.

The only fireproofing specified in the building is a vermiculite-gypsum on metal lath envelope around the structural steel columns and framing. No fireproofing of any kind is required to protect the metal underside of the composite-form slab. Standard fire tests have shown that this floor construction will safely provide 3 hours of fire protection.



Permanent composite-forms are tack-welded to the steel frame of the Bethesda Lutheran Infirmary. Flooring provides level, unobstructed working surface for all construction trades.



Unprotected composite-form floor is rated at 3 hours of fire resistance. Columns achieve 4-hour rating with 1¾-inch vermiculite-gypsum plaster on self-furring metal lath.

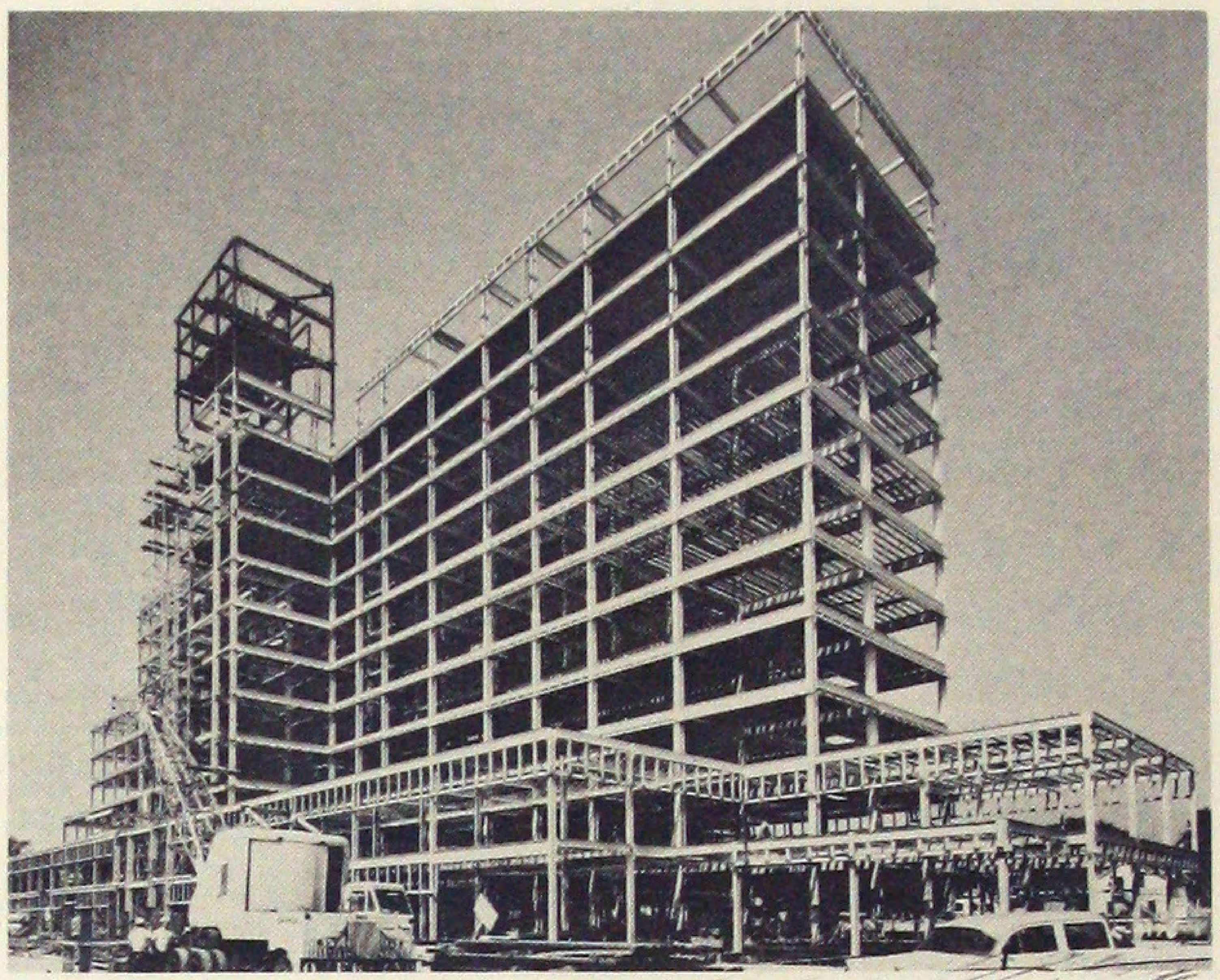
Economy and fire-safety in model Naval Hospital

Building Code: U. S. Navy Design Specifications
Fire Resistance Ratings:
Columns and Spandrel Beams: 4 hours
Floors and Floor Framing: 3 hours
Roofs and Roof Framing: 2 hours
Architect-engineer: Schmidt, Garden & Erickson, Chicago

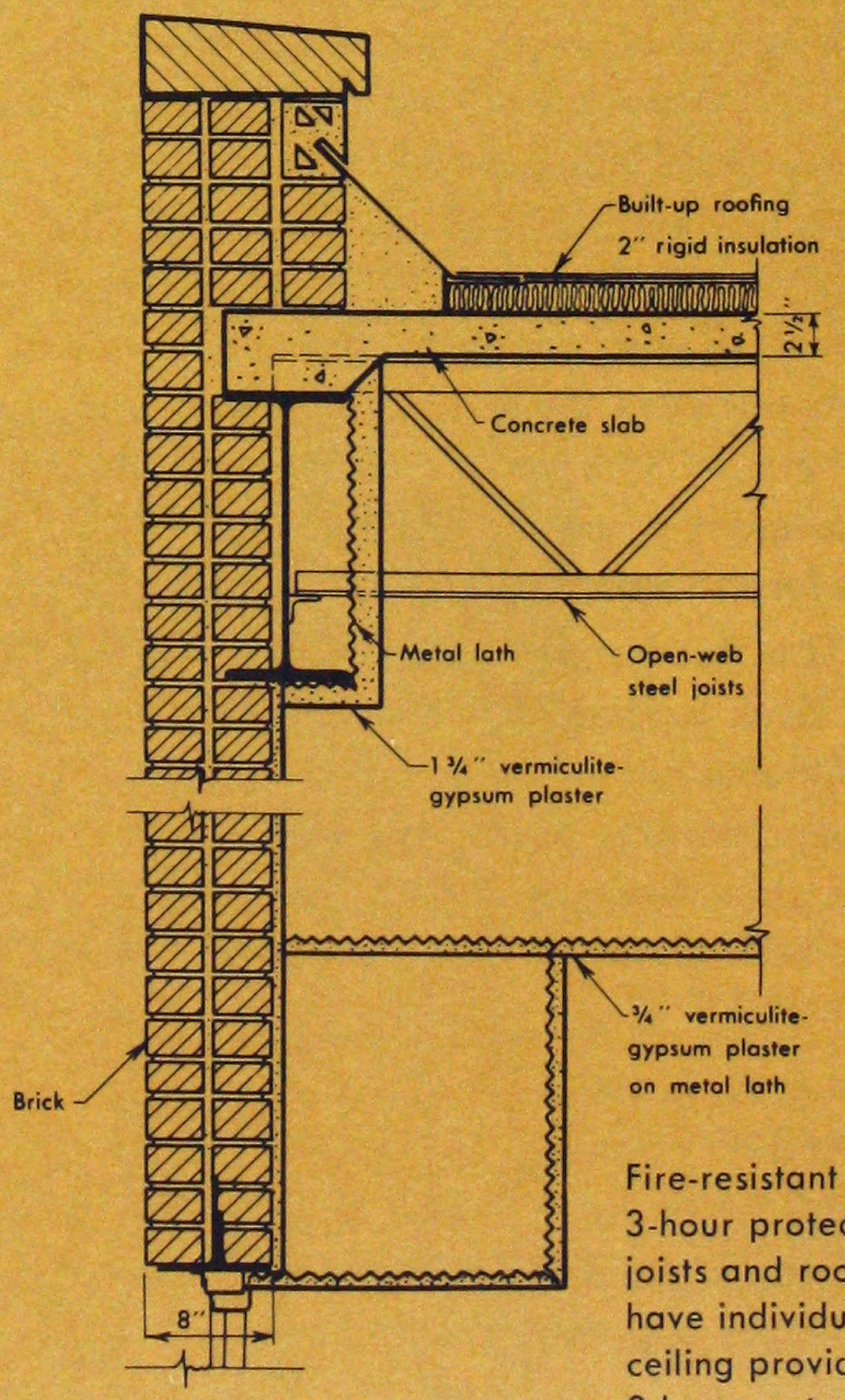
Two years of intensive study, planning and research were expended by architects-engineers Schmidt, Garden and Erikson in the design of the modern 12-story, 800-bed U. S. Naval Hospital at Great Lakes, Illinois. The result is one of the finest, most completely equipped and skillfully planned service hospitals in the United States—designed with *light-frame* fire-resistant steel construction.

U. S. Navy specifications for this multi-story hospital construction required a 4-hour fire resistance rating for columns, and a 3-hour rating for floors and framing. The designers, while fulfilling these fire-safety requirements, were also concerned with three main items—economy, minimum construction time, and maximum useable floor area. A thorough investigation was made to determine the design which best suited all of these requirements. Preliminary studies and alternate designs were made of a typical bay framed in reinforced concrete and in structural steel, each designed to achieve the specified fire resistance ratings. The results clearly showed that structural steel, protected by lightweight fireproofing, was more economical than any alternate design, reduced construction time by 4 to 6 months, and required 3½ feet less building height for the same clear interior floor heights. The steel design permitted fewer columns, and in many cases the fireproofed steel columns occupied less than half the floor area required by equivalent concrete columns.

Typical floor construction in this 15-million dollar model hospital is a 2½-inch concrete slab on steel joists, fire-protected by a ¾-inch membrane ceiling of vermiculite-gypsum plaster on metal lath. Columns are wrapped in an envelope of lightweight plaster. In kitchen areas concrete encasement of columns is used to minimize damage from moving carts and other equipment.



U. S. Naval Hospital at Great Lakes, Illinois, built under the direction of the Navy Bureau of Yards and Docks. *Light-frame* steel construction was found to be more economical and efficient than any alternate design.



Fire-resistant ceiling provides 3-hour protection to open-web joists and roof. Spandrel beams have individual 4-hour protection; ceiling provides an additional 3-hour protection when bottom flange of beam is above the ceiling line.

Insurance Company utilizes lightweight fire protection

Building Code: Los Angeles
Classification: Type 1, Group G
Required Fire Resistance Ratings:
Columns, Beams and Girders: 3 hours
Floors and Roofs: 2 hours
Architect: Claude Beelman & Associates, Los Angeles
Structural Engineer: Brandow & Johnston, Los Angeles

Few groups are more aware of fire hazards and the importance of dependable fire-protective materials and techniques than insurance companies. It is therefore significant that so many of these companies have recognized the advantages of lightweight fireproofing materials and are building with *light-frame* fire-resistant steel construction. The Continental Assurance Company, The Prudential Insurance Company, The Security Mutual Life Insurance Company, the Life and Casualty Insurance Company, The State Mutual Company of America, The Guarantee Mutual Life Insurance Company are among the many insurance organizations that have recently constructed fire-resistant steel-framed buildings in every section of the United States.

One of the newest of these is the 7-story Continental Companies office building in Los Angeles, home of the Continental Assurance Company. The structural steel frame of this 3-million dollar building is fire protected with lightweight vermiculite-gypsum plaster, machine applied to metal lath which encloses the interior columns and beams. The exterior columns are fireproofed with concrete encasement poured simultaneously with the concrete for the exterior walls.

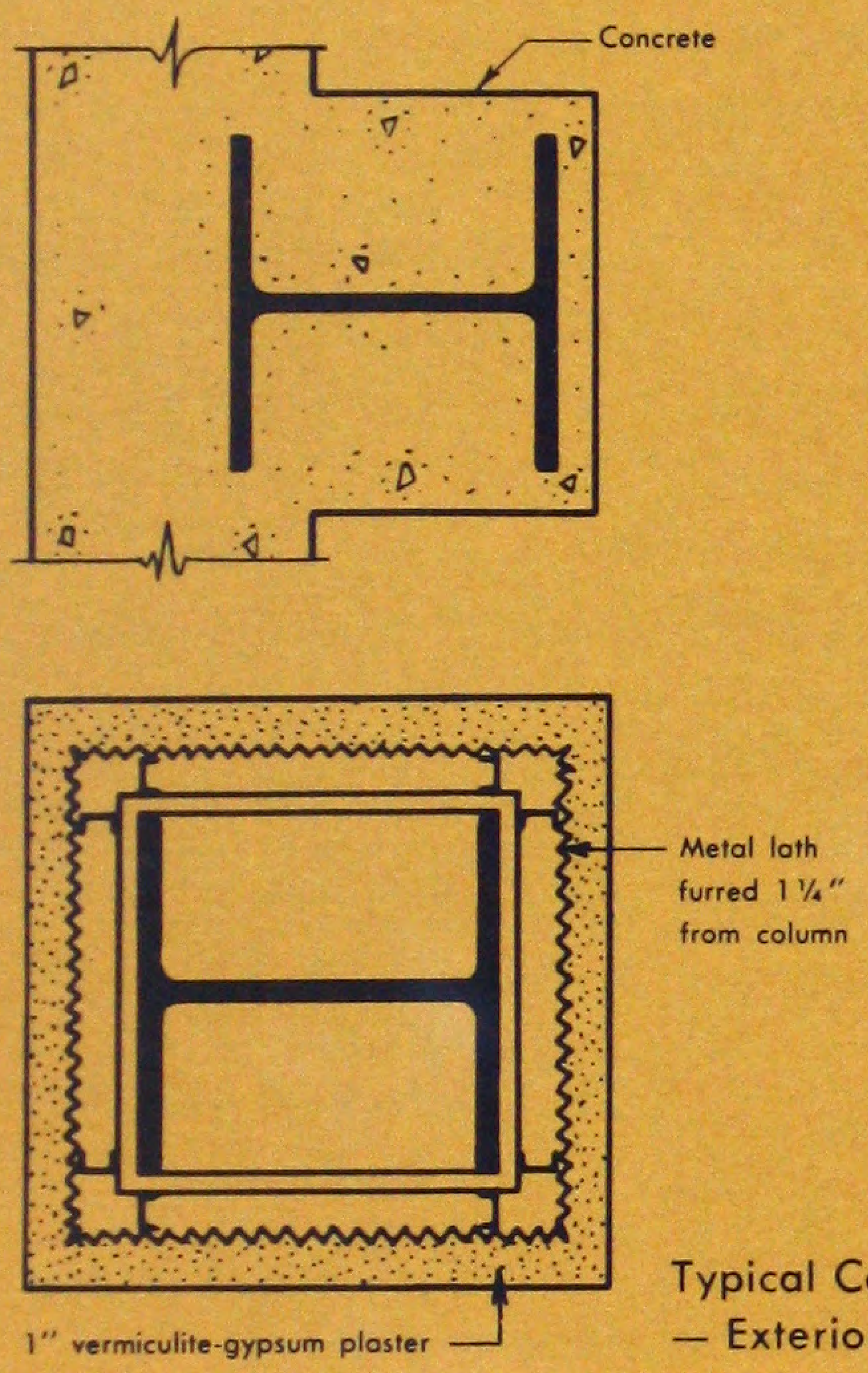
The floor construction consists of a cellular steel deck topped with 2½ inches of concrete fill. Vermiculite acoustic plaster was sprayed directly to the underside of the cellular floor to attain the 2-hour fire resistance rating required by the Los Angeles building code.

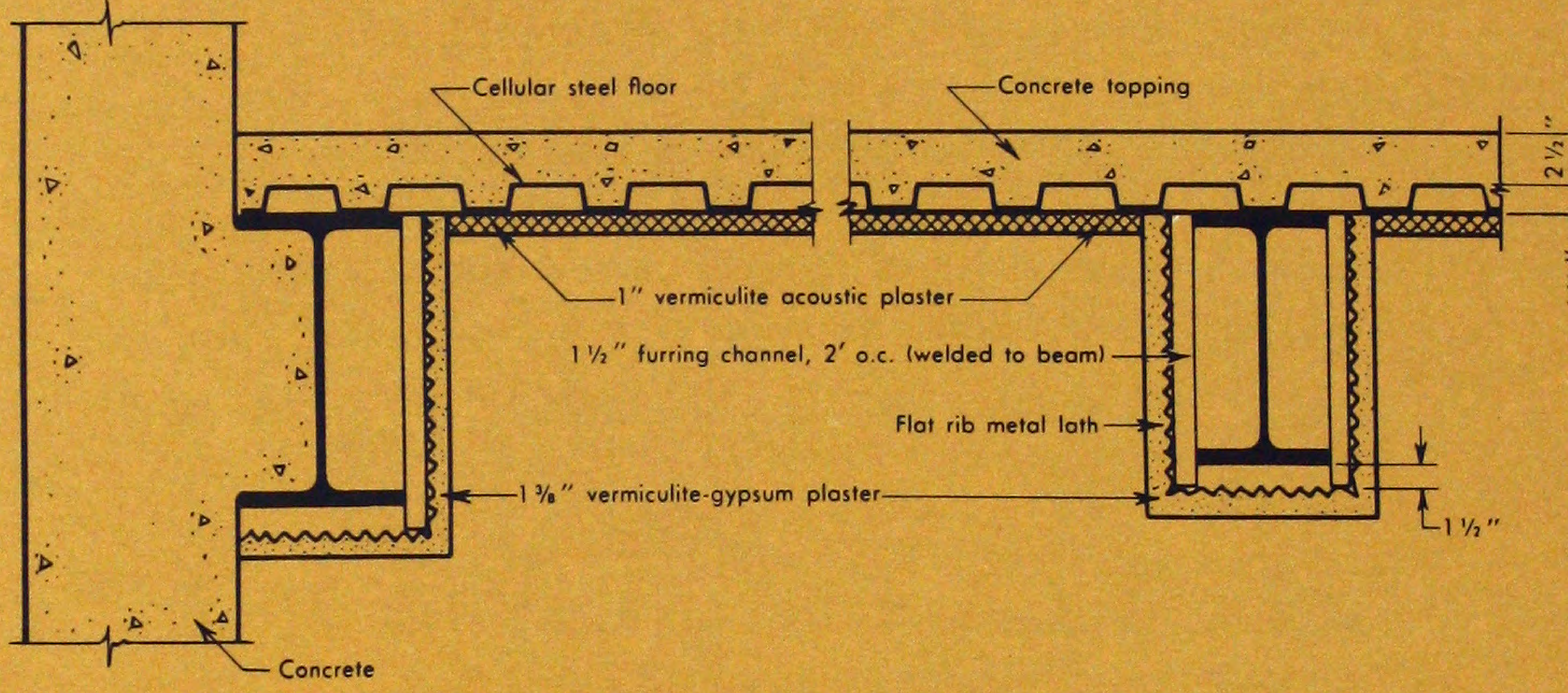
Hanger wires for piping, air conditioning ducts, and for the channel runners which support a suspended acoustic tile ceiling, were dropped through holes in the steel floor units before fireproofing. Pigtails are made in the wires to prevent them from slipping through the floor units. The suspended ceiling does not contribute to the fire resistance of the assembly.

Dead load reduction permitted economical design of large column-free areas.

The Continental Companies Building is 105-feet x 157-feet and has about 115,000 square feet of floor space exclusive of basement and penthouse areas. Aside from a central utility core, there are only four interior columns on each floor. The wide spacing of the columns in the outside bays added little to the cost of the building, according to Architects Claude Beelman & Associates, but permitted a high degree of flexibility of office layout in a large open space. The owners contemplate that should their space requirements ever exceed the use of all floors, the building could easily be converted to a department store or other occupancy requiring open floor space.

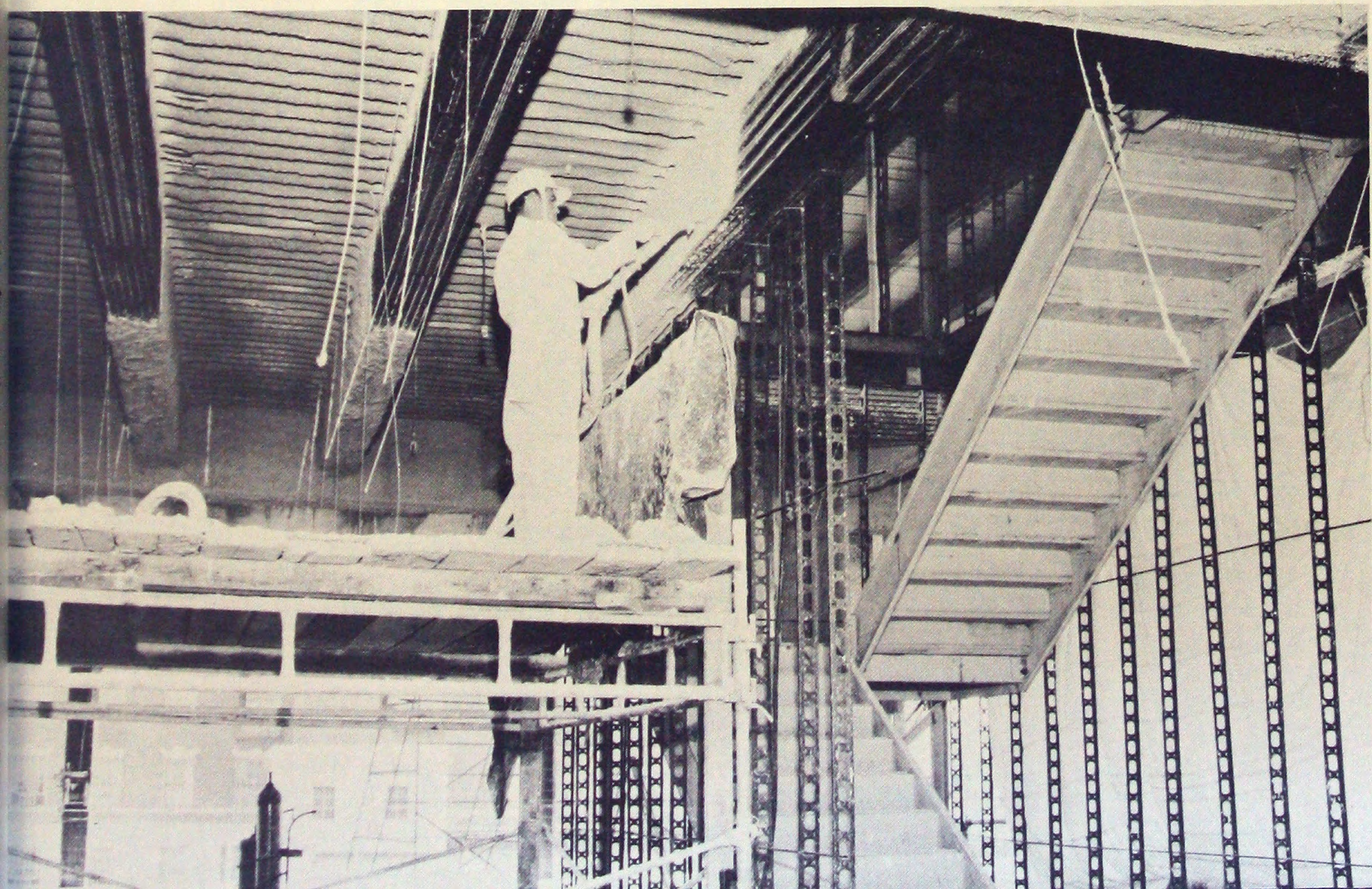
New 7-story *light-frame* fire-resistant Continental Companies Building is protected by sprayed-on lightweight fireproofing.





First coat of acoustic plaster was sprayed on ⅝-inch thick and leveled. The ⅜-inch second coat was not hand-finished since the fireproofing is not exposed. A gauge was used to assure uniform thickness. Fluted steel decking was used instead of cellular floors in the service core where extensive electrical facilities were not required.

Typical Column Construction
— Exterior and Interior



Journeymen worked from small rolling scaffolds to fireproof floors and beams. Building was fireproofed while walls were still going up. Stairs were installed immediately after erection of steel, and fireproofing was later sprayed into small openings where stair stringers passed beams.

Low-cost fire-resistant construction for FHA-financed

Building Code: Uniform Building Code
Classification: Group H, Type 1
Required Fire Resistance Ratings:
Columns and Primary Beams: 3 hours
Floors, Roofs and Secondary Beams: 2 hours*
Architect: Merchant & Shelley, Long Beach
Structural Engineer: Bole & Wilson, Long Beach

* Note: Designed to a 4-hour rating.

Largest "own-your-own" FHA-financed cooperative apartment house west of the Mississippi is the beautiful 11-story Royal Palms Apartments in Long Beach, California. Architects Francis O. Merchant, A.I.A. and J. Richard Shelley, A.I.A. have designed a "luxury" type fire-resistant residential building, yet construction costs were less than those of many lower quality, low-rental apartment houses.

Completed in early 1959, the plan of the building is shaped like a cross, and is placed diagonally on a 150-foot x 150-foot site. There are 162 apartments and two penthouses in the project, as well as basement parking facilities for 82 cars. More than half of the apartments enjoy a view of the Pacific Ocean. The apartments have one or two bedrooms, and range in price from $10,500 to $20,000. The penthouses contain six rooms and two baths, and cost $50,000 each. Total building costs amounted to $2,100,000, approximately $10.50 per square foot of gross floor area.

The exterior facing of the building is a combination of concrete shear walls, porcelain enamel spandrels, and glass. The steel columns at the shear walls are concrete fireproofed. Interior columns and exterior columns at the curtain walls are enclosed in a fire-resistant box of perlite-gypsum plaster on two layers of plain gypsum lath. The basement garage is equipped with an automatic sprinkler system.

Typical floor construction is a 3¾-inch reinforced concrete slab supported on intermediate steel beams. Both the concrete slab and the steel framing are protected by a fire-resistant suspended ceiling of perlite-gypsum plaster on gypsum lath. This membrane fireproofing provides a 3-hour fire resistance rating for the floor system. A similar ceiling of acoustic plaster on metal lath is used in the lobby area to provide sound control as well as fire protection.

Each apartment is provided with an independent forced air heating system, thermostatically controlled. Four 2-million BTU boilers provide steam to heat exchangers on each floor, where air is heated and forced through independent duct systems. All ducts are hidden from view by the suspended fire-resistant ceilings.

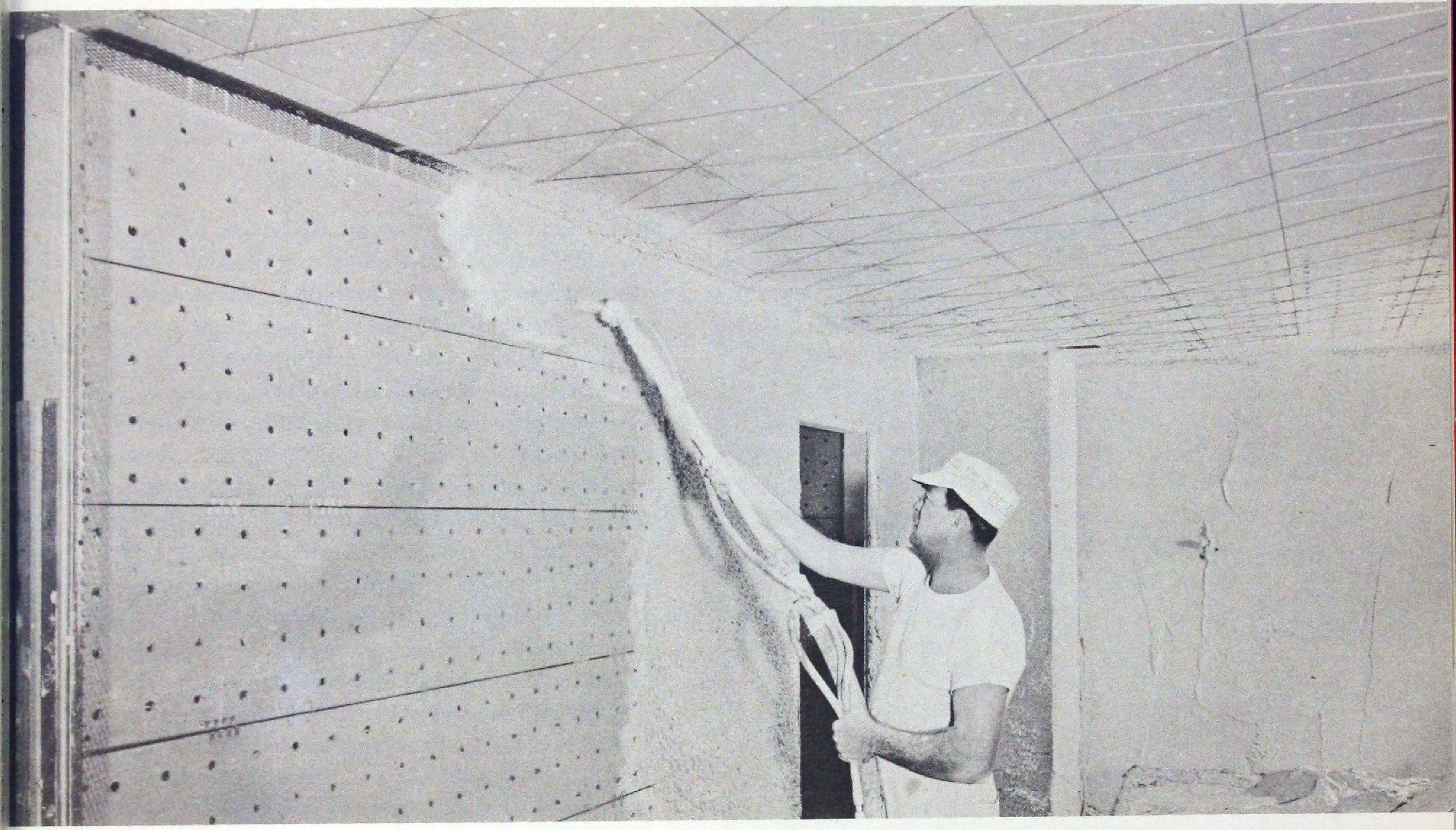
One of the economies of plaster fireproofing in residential construction is that the lathing and plastering of both the fire-resistant ceilings and partitions can be performed as one continuous operation. In this case all partitions were built with gypsum lath of the same type used in the membrane fireproofing. Hollow steel stud partitions were provided between apartments and in corridors, and 2-inch solid studless partitions were used elsewhere. Because the same materials were used in all interior fireproofing and all partitions, unit costs for the plastering contractor were considerably reduced.

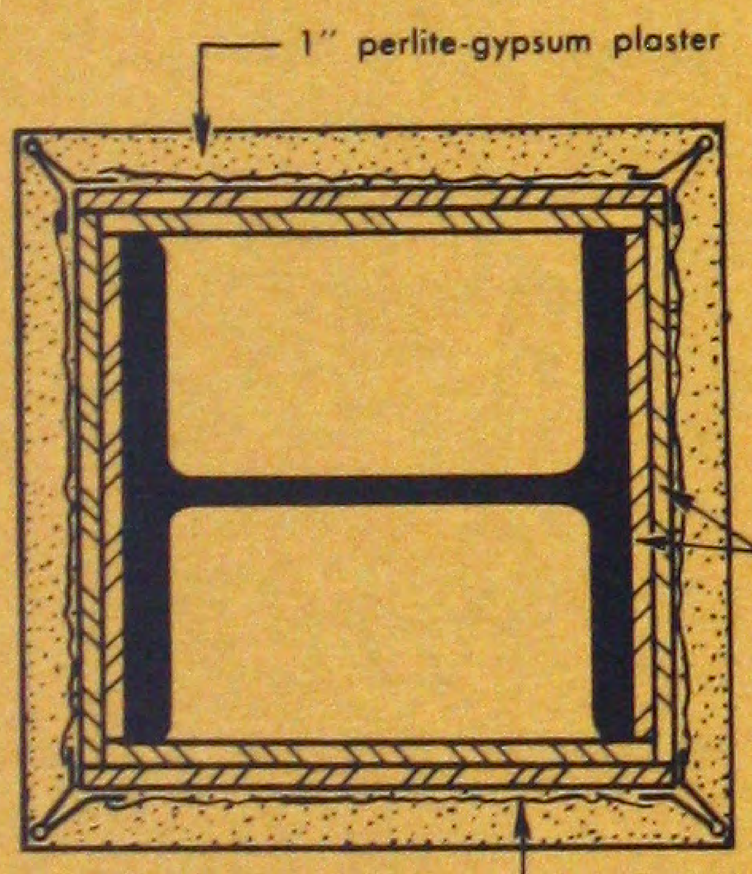
In the Royal Palms Apartments, as in so many other residential buildings, steel framing protected by membrane fireproofing was found to offer maximum economy with no sacrifice in quality.

Royal Palms Apartments looks out to the Pacific at Long Beach, California. Cost per square foot of construction was lower than that of many low-rental apartment houses.

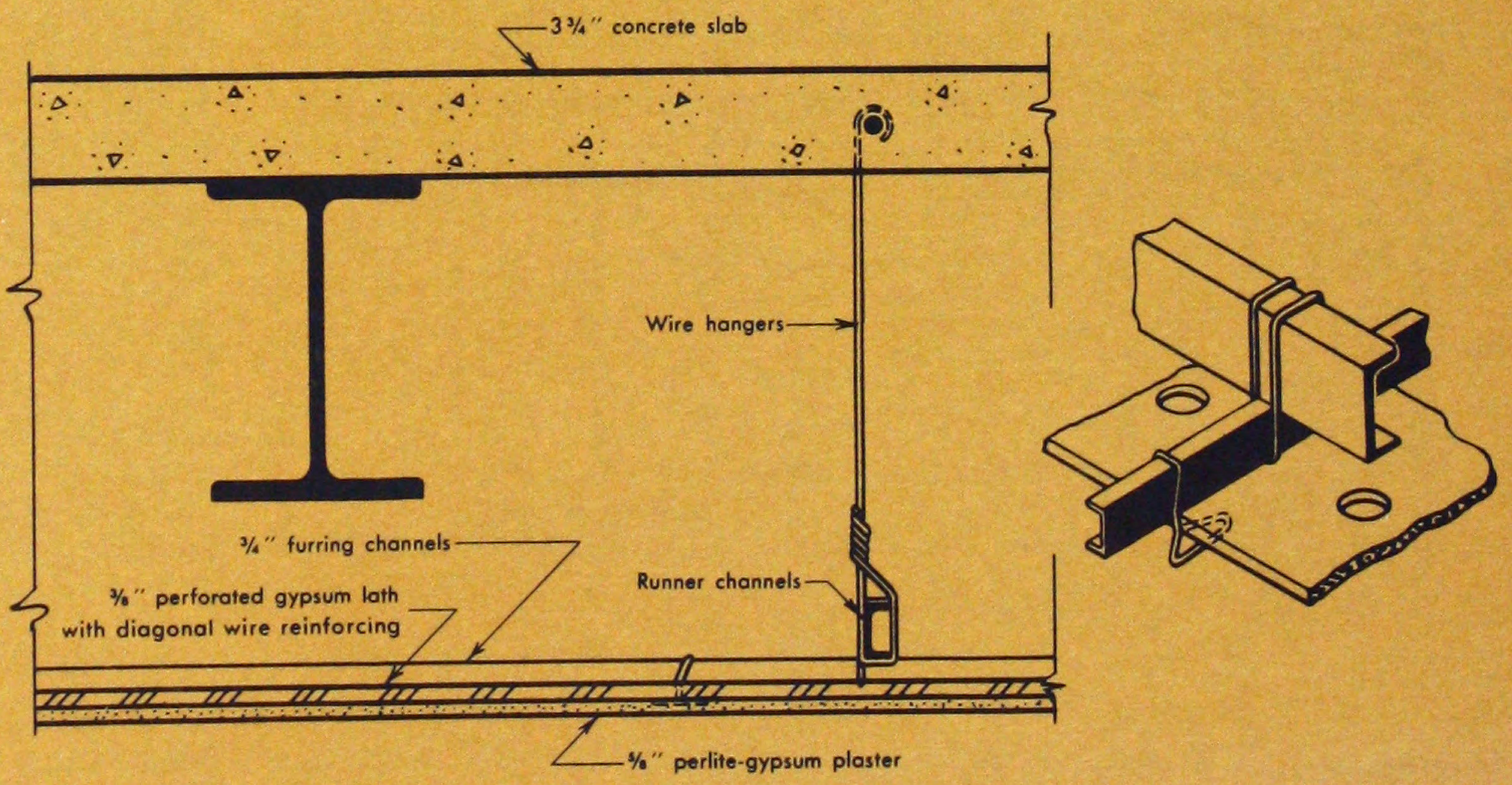
Luxury Apartments

Base coat of perlite-gypsum plaster was applied over gypsum lath of walls and ceilings as a continuous operation. Note diagonal wire reinforcing over ceiling lath.





Typical interior column



Membrane fireproofing provided 3-hour rating to steel beams and concrete slab. In the lobby area ½-inch acoustic plaster over a base coat of ⅝ inch perlite-gypsum plaster on metal lath achieved the same rating.

Fire-resistant design reduces insurance costs

Building Code: Dallas, Texas

Classification: Type I, Class F

Required Fire Resistance Ratings:

Columns and Spandrel Beams: 3 hours*

Floors and Floor Framing: 2 hours*

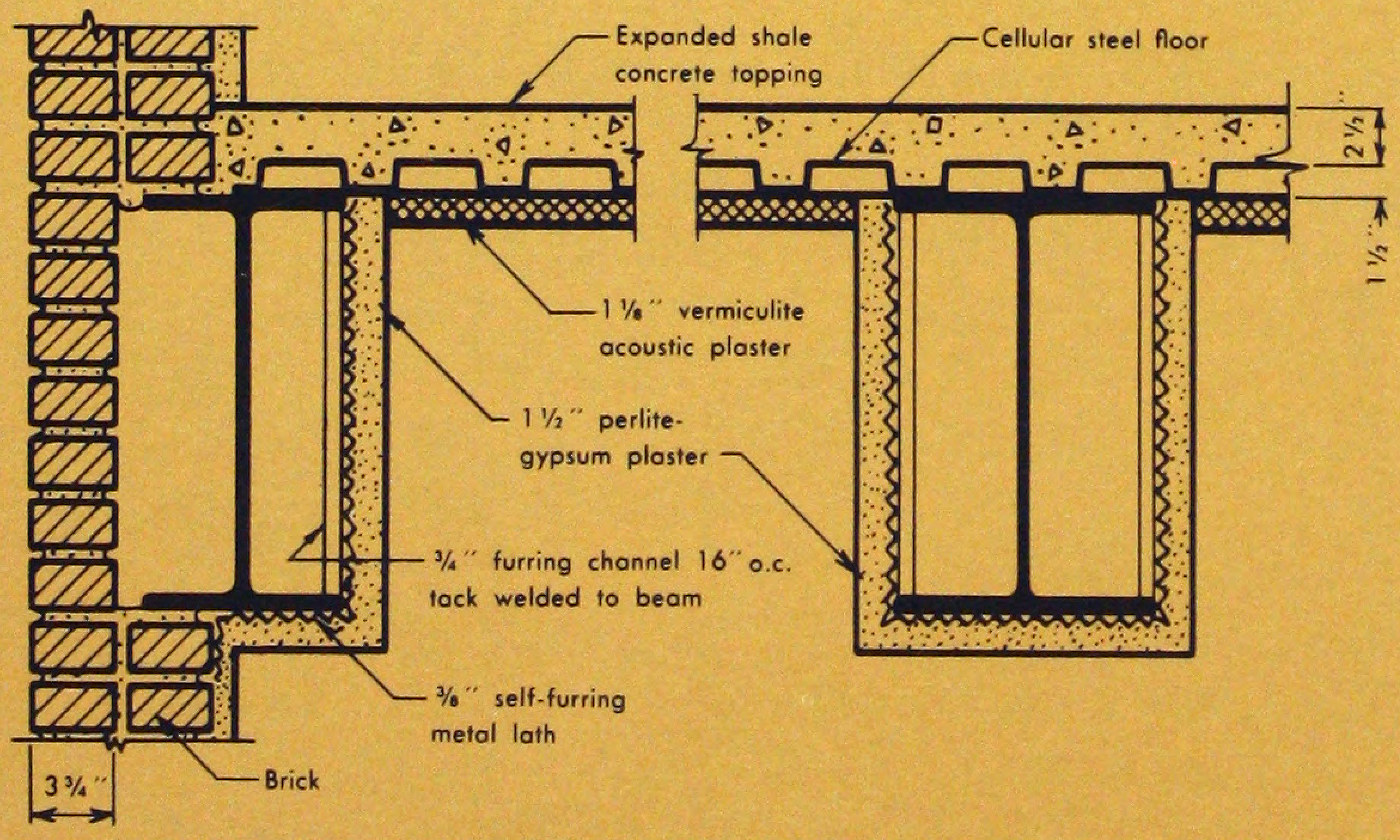
Roofs and Roof Framing: 1 hour*

Architect-engineer: Lane, Gamble and Associates, Dallas

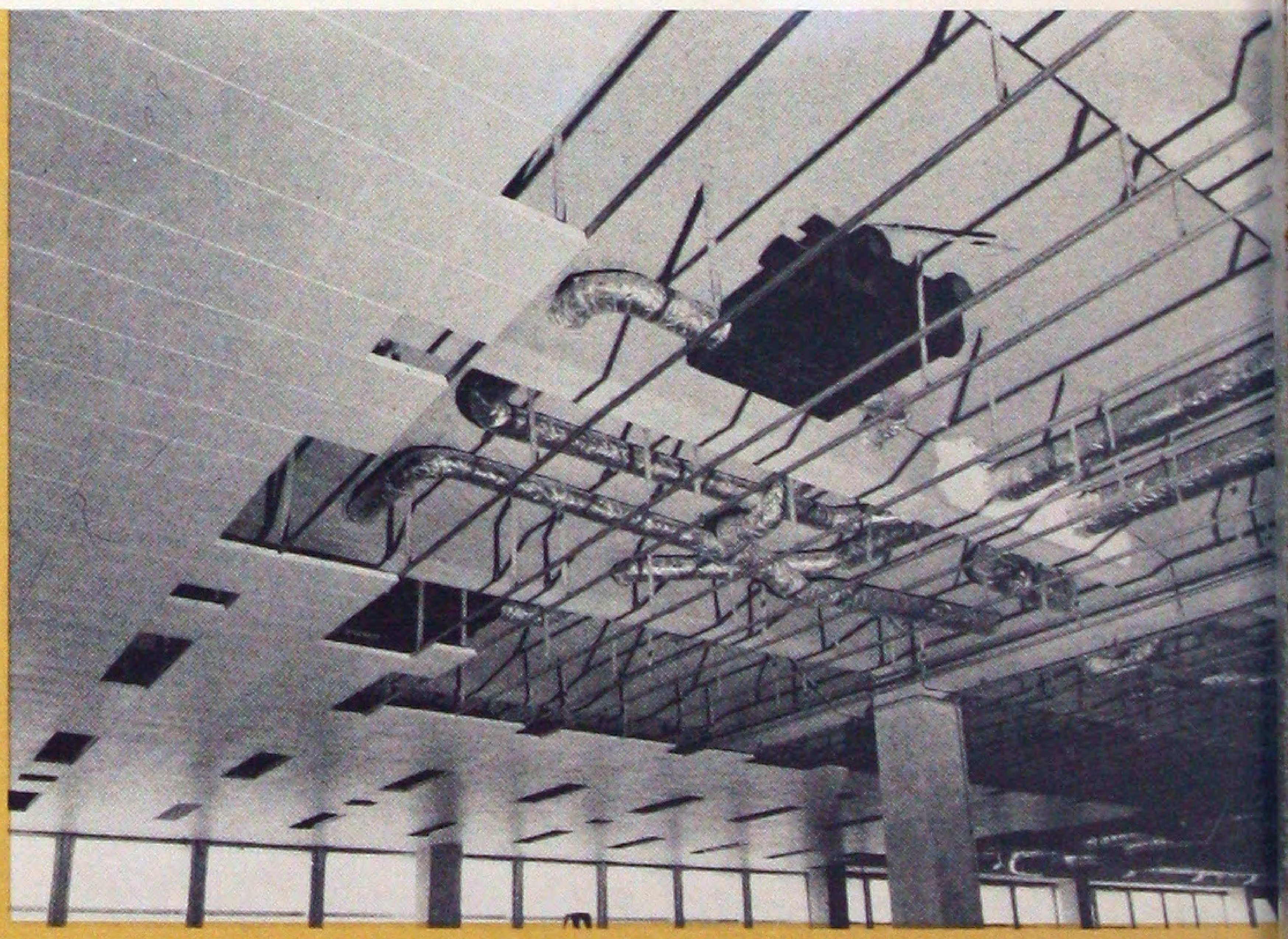
* Note: All components were designed to a 4-hour fire resistance rating.

Not often do provisions beyond building code requirements result in economical construction. Yet architects Lane, Gamble & Associates deliberately made such provisions for the fire protection of the new Exchange Bank Building in Dallas, Texas—and saved money. The key to this unusual situation was the cost of fire insurance. Although the Dallas code required only a 2-hour fire resistance rating for the floor construction and a 3-hour rating for the columns and spandrel beams, the designers provided 4-hour protection for all structural components in order to obtain the lowest possible insurance rating. The relatively small cost of increased fireproofing required to achieve this extra margin of fire safety will soon be recovered through reduced insurance premiums. Because the actual fire resistance desired can easily be achieved in steel frame construction, an increasing number of owners, architects and engineers are evaluating fire-resistant design in the light of potential annual savings in insurance costs.

The flexibility of design of fire-resistant steel construction solved still another problem faced by the designers of the Exchange Bank Building. Because the building is close to Love Field Airport, Civil Aeronautics Authority regulations limited the overall height of the structure to 170 feet. By employing contact vermiculite acoustic plaster fireproofing sprayed directly to the underside of a cellular steel floor, and by running pipe ducts through the webs of steel beams instead of below the framing, the designers were able to build 13 stories where only 11 stories would have been possible with more conventional construction.



Typical beam and floor fireproofing.



Cellular floor is protected with directly applied vermiculite acoustic plaster and lightweight concrete topping. Beams and girders are protected by perlite-gypsum plaster on metal lath. Note how ducts pass through cutouts in webs of steel framing. Metal pan acoustic ceiling conceals mechanical work.

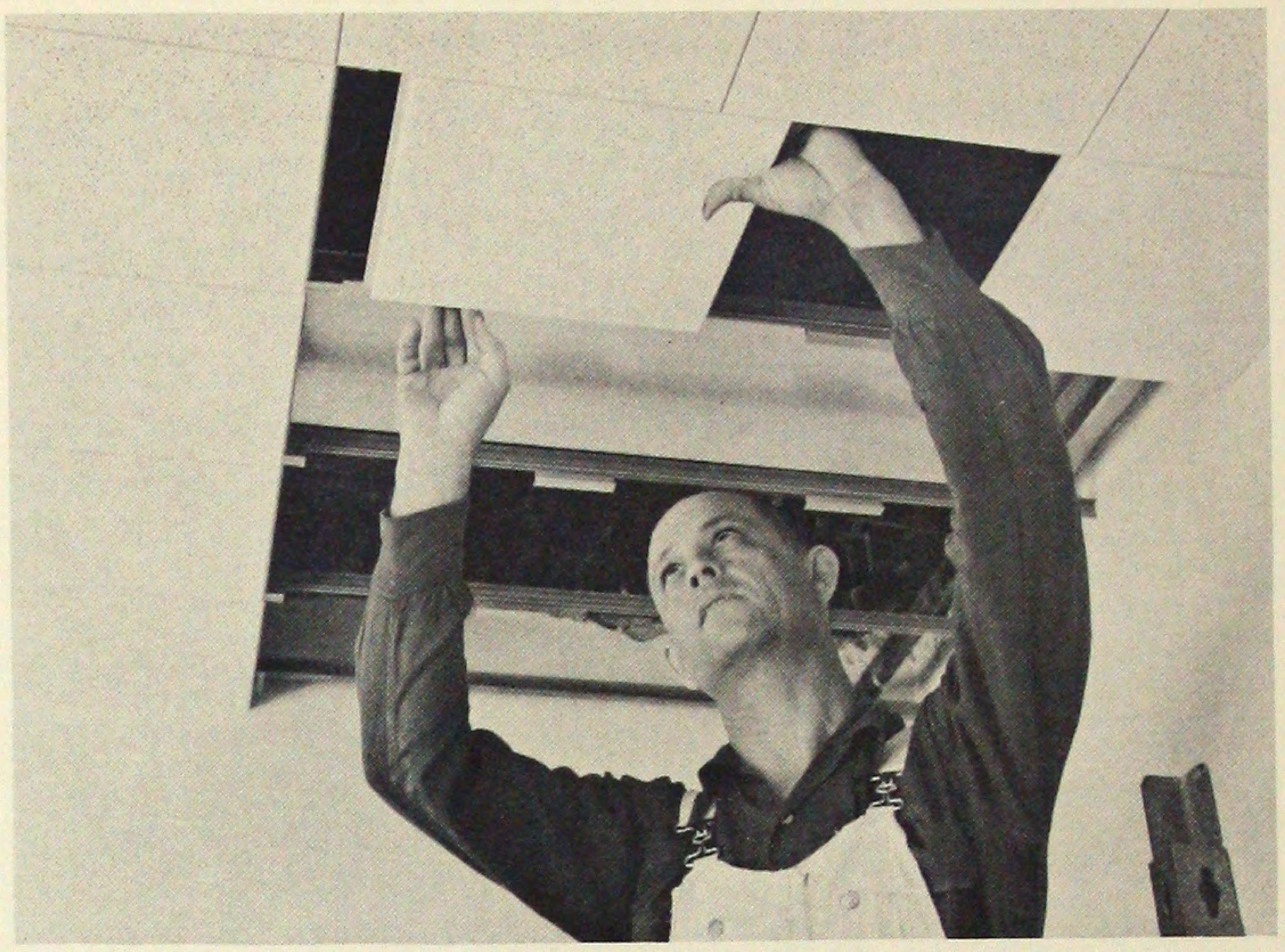
Acoustic tiles protect modern Medical Center

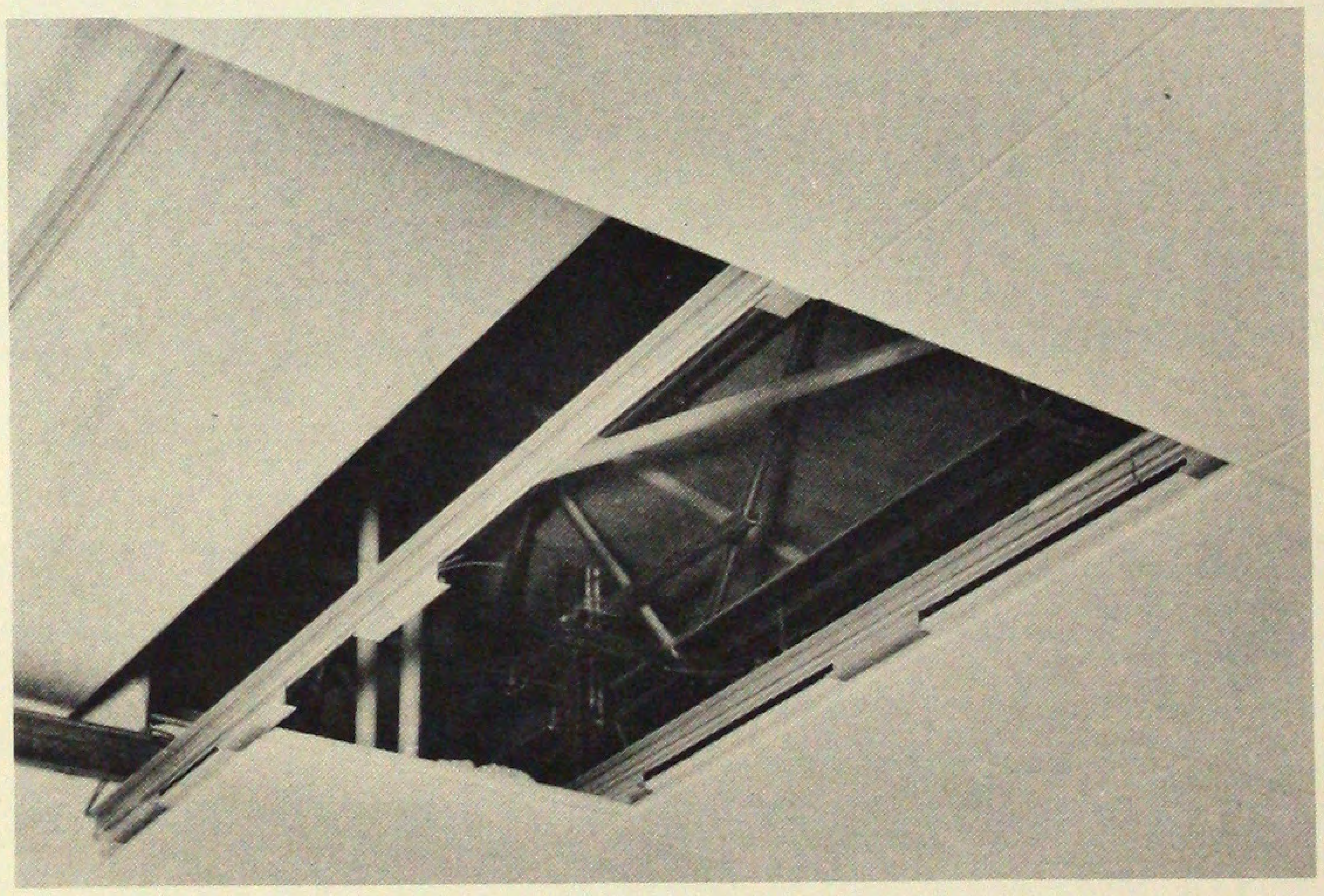
Building Code: St. Louis, Missouri
Classification: Class II
Required Fire Resistance Ratings:
Exterior Columns and Spandrel Beams:
4 hours
Interior Columns, Beams and Floors:
2 hours
Roof: 1 hour
Architect-engineer: Robert Graham

The future promises even more than the past in the development of practical, economical fire-resistant steel construction. New fireproofing products, fire-tested to meet the requirements of modern building codes, offer new opportunities for efficient, flexible fire-resistant design. Architect Robert Graham specified one of the newest of these products, a densely packed mineral fiber acoustic tile, as membrane fireproofing for the floors, roof and steel framing of the St. Louis Hills Medical Center, St. Louis, Missouri.

Typical floor construction in this 3-story professional building is a lightweight concrete slab on open-web steel joists. The structural steel framing supporting the joists is a simple beam and column arrangement with 20-foot wide bays. Protecting the floors and framing, and providing sound conditioning in the office areas, is a suspended fire-resistant ceiling of mineral fiber acoustic tiles. In corridors and service areas, where acoustical treatment is not required, a ceiling of vermiculite-gypsum plaster on metal lath is used instead of the acoustic tile. Both ceilings provide the 2-hour fire resistance required by the St. Louis building code. Interior columns are enclosed with lightweight plaster fireproofing. Exterior columns and spandrel beams are encased in the solid brick exterior wall. A basement parking garage is protected by an automatic sprinkler system.

The acoustic tile fireproofing consists of 12-inch x 12-inch tongued-and-grooved tiles supported by clip splines which snap into main runners spaced 12 inches on center. Where border tiles butt against the office walls, nailing channels replace the runners, and special border splines are used. Border tiles are carefully scribe-cut to fit accurately against the wall plaster which extends 3 to 4 inches above the ceiling line.





(top) Densely packed mineral fiber tiles have coated faces. The ceiling provides fire resistance, sound conditioning, and an attractive finished appearance.

(bottom) A clip spline suspension system supports the ¾-inch thick acoustic tiles at the grooved edges.

The building is completely air-conditioned, and duct work as well as electrical and plumbing lines are placed in the cavity space above the ceiling. If emergency repairs or alterations to the concealed mechanical or electrical work is ever required, portions of the ceiling can be quickly removed, and replacement of the ceiling will be easy and economical.

Light-frame construction in suburban office building

Building Code: Wisconsin State Building Code
Classification: Fire-resistive
Required Fire Resistance Ratings:
Columns, Beams and Girders: 4 hours
Floors and Roofs: 2 hours*
Architect-engineer: John J. Flad & Associates, Madison

* Note: Floors and roofs were designed to a 3-hour fire resistance rating.

The designers of modern buildings are continually rediscovering the versatility of fire-resistant steel construction. Literally hundreds of tested fire-resistant floor and roof constructions are more compatible with structural steel framing than with any other type of construction. The designer is free to choose from a wide variety of competitive materials and systems which will best meet his architectural, engineering and building code requirements.

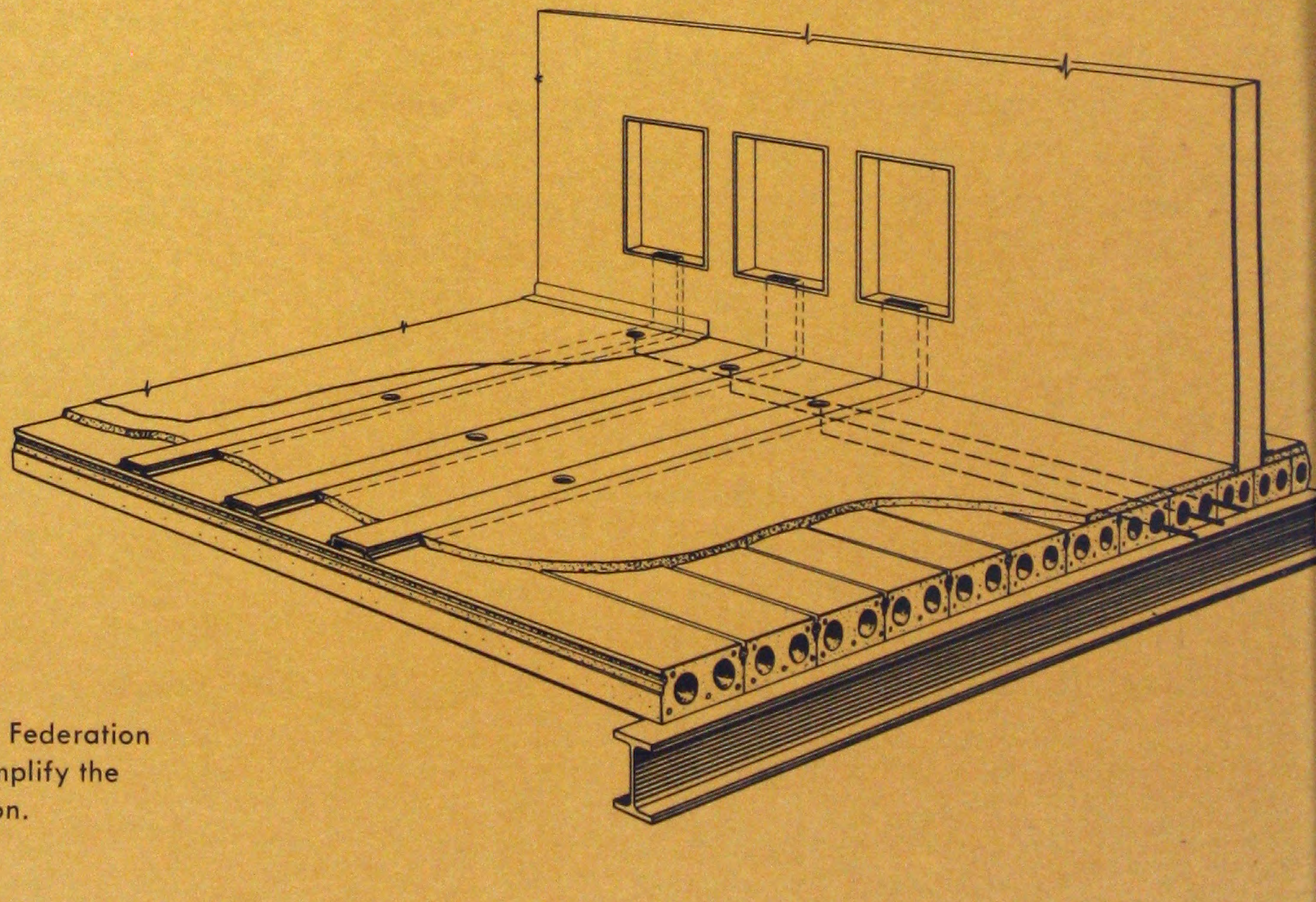
When architects-engineers John J. Flad & Associates were designing the new 3-story suburban offices of the Wisconsin Farm Bureau Federation in Madison, Wisconsin, they sought the fire-resistant construction which would provide maximum economy, flexibility, fire-safety, and speed of construction. Their investigation led to the selection of a *light-frame* steel structure with precast concrete cellular floors and roofs.

The Wisconsin Building Code calls for 2-hour fire-resistant floors and roofs, and a 4-hour structural frame. The designers specified a precast cellular slab system which had been fire-tested under ASTM standard test procedures and had achieved a 3-hour fire resistance rating without any fireproofing under the slab. High grade limestone aggregate concrete was specified, and each slab was cast monolithically under close quality controls. The structural steel beams, girders and columns were protected with a cage of vermiculite-gypsum plaster on metal lath.

The 8-inch deep x 16-inch wide precast slabs span typical 20-foot x 20-foot bays without intermediate supports. Weld plates, precast into the ends of every fourth slab unit, are field welded to the structural steel to provide lateral bracing and to fasten the floor system to the framing. All roofs

Attractive suburban offices of Wisconsin Farm Bureau Federation and Affiliated Companies in Madison, Wisconsin exemplify the versatility of *light-frame* fire-resistant steel construction.

Header ducts connect telephone, electrical, and spare panel boxes to cells in precast floor. Each system uses a separate group of cells.

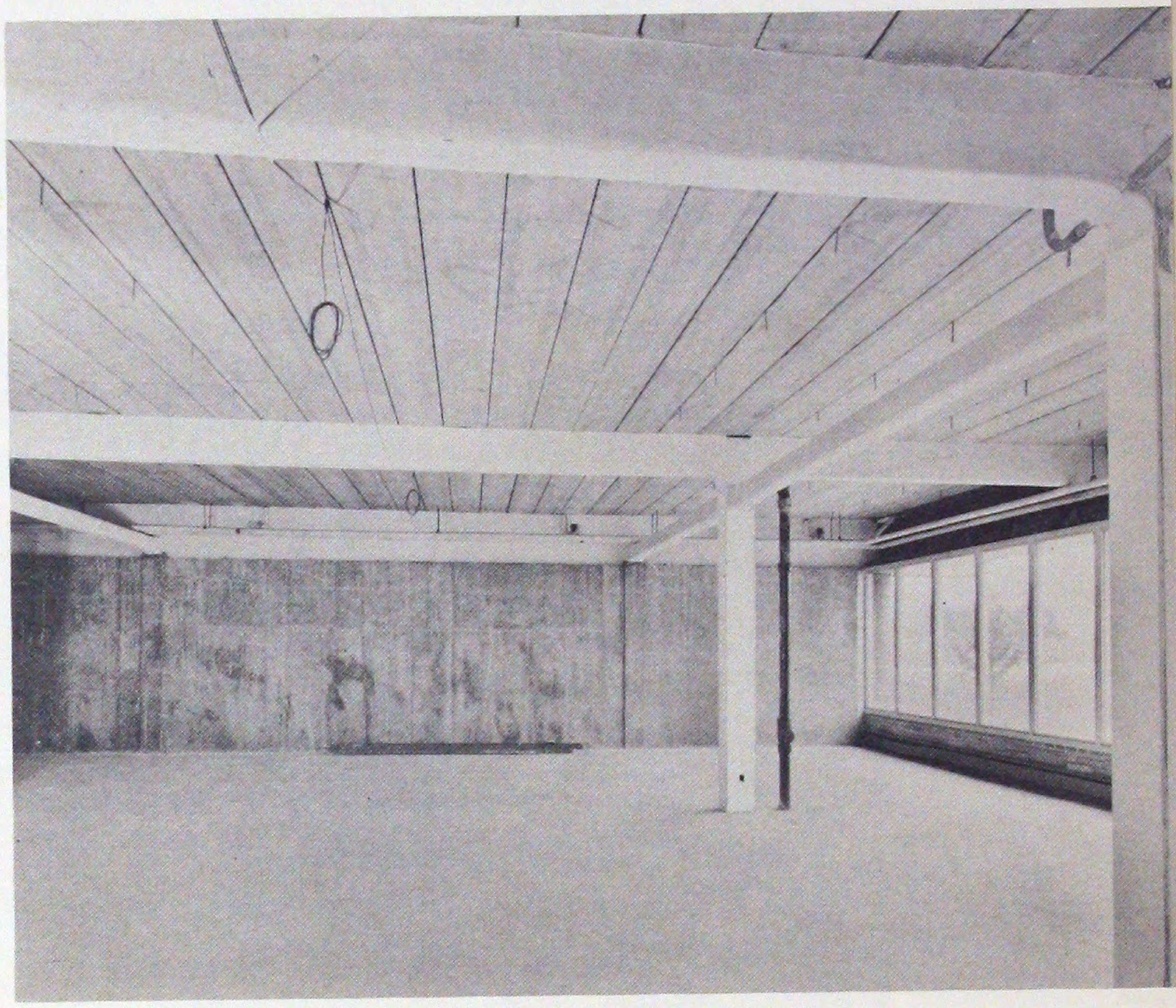


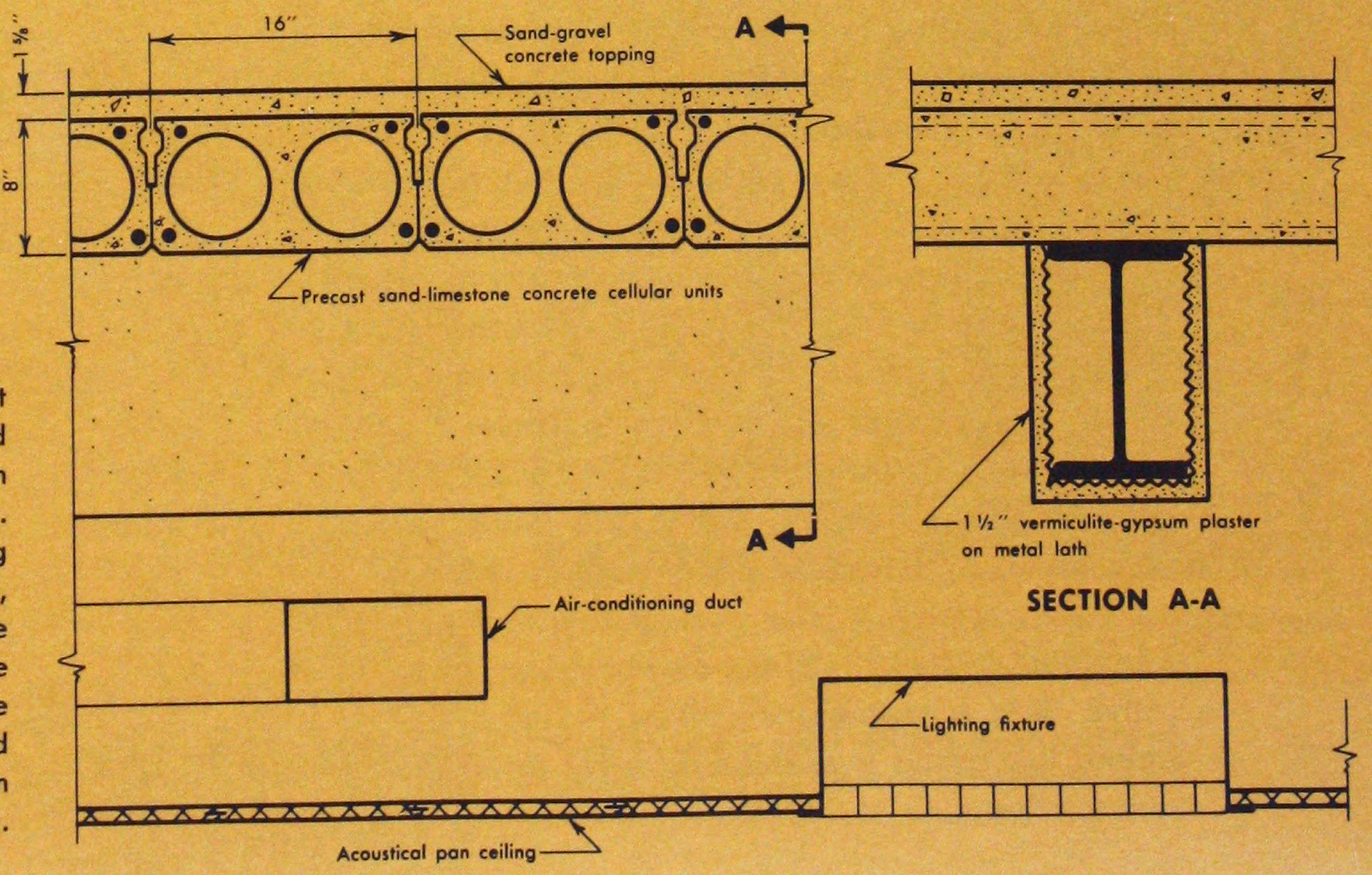
are designed to be used as floors for an additional story.

Ceilings in the office area are of suspended acoustic pan construction with lighting fixtures and air-conditioning diffusers recessed into the space above. The spaces between ceilings and floors accommodate all ductwork. Because the fire-resistant construction is above the ceiling, the size and location of duct openings are not restricted by code requirements. Movable walls are used for office partitions.

The continuous hollow cells in the floor form electrical raceways for all electrical needs other than lighting. Header ducts are buried in the fill over the precast units and feed the raceways in the slab units. If additional electric outlets are needed in the future, they may be installed by drilling through the floor at any point directly above a raceway, fishing wire through the openings, and installing the outlet box.

Simplicity of the structural steel design is illustrated by this view of an unfinished ground floor area. Beams and columns are already enclosed in lightweight plaster fireproofing. No other fire protection is required. Note the steel hangers in floor joints for attachment of utilities and suspended acoustical ceiling.





Fire-tested monolithically precast concrete cellular slab is rated at 3-hour fire resistance when topped with 1 ½-inch concrete. Suspended acoustical ceiling screens air-conditioning ducts, but does not contribute to fire resistance. In buildings where no ductwork is required, these cellular units are often caulked and painted to serve as an attractive finished ceiling.

Unusual fireproofing combination in San Francisco's

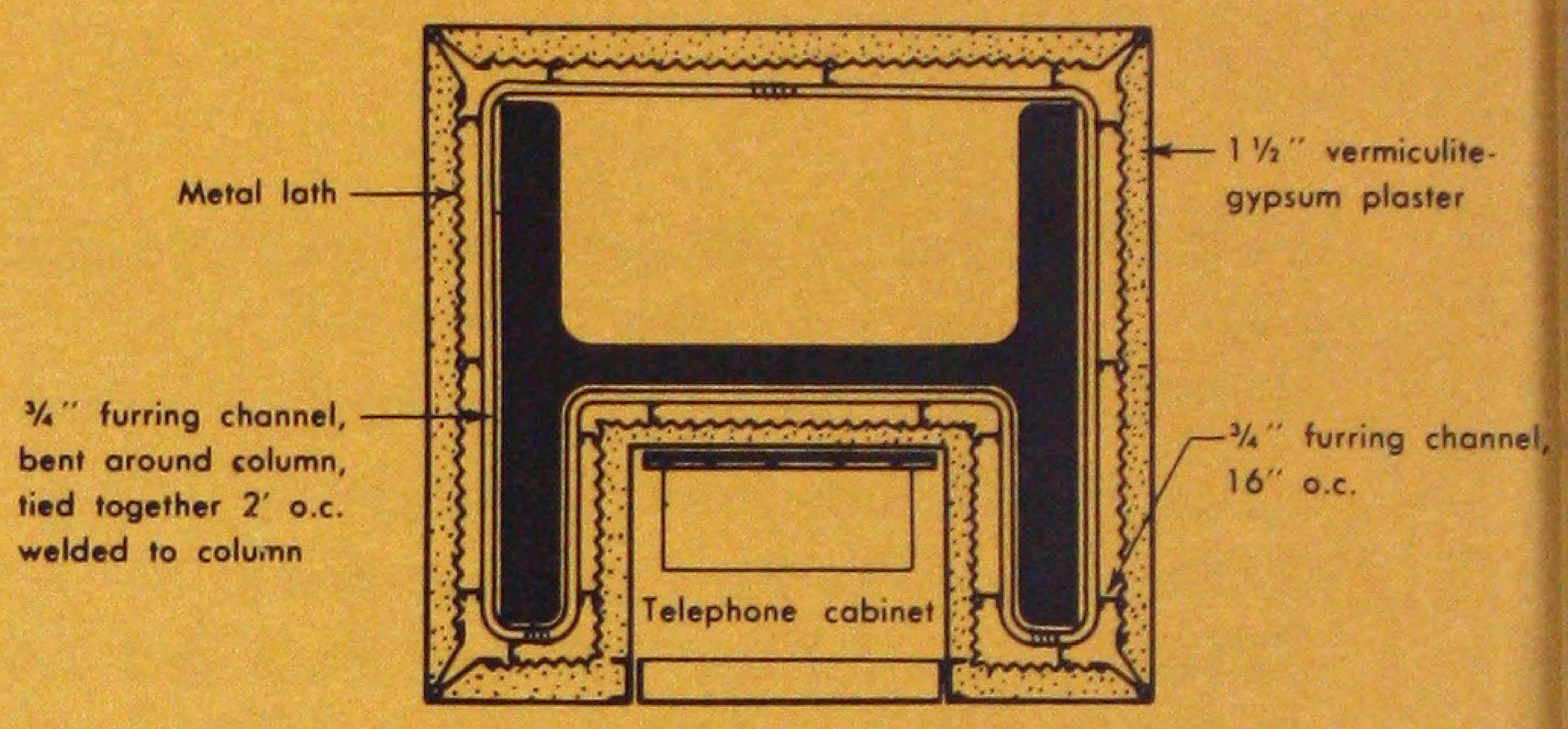
Building Code: San Francisco

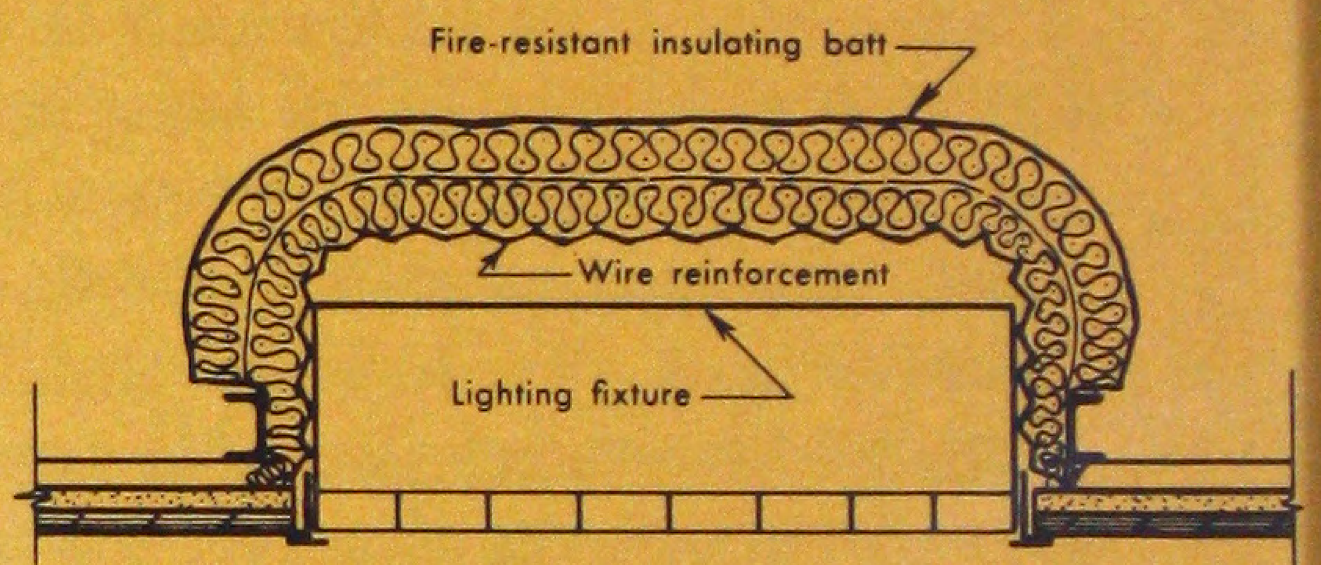
Classification: Type I, Class 16, Division 2

Required Fire Resistance Ratings:
- Columns and Spandrel Beams: 4 hours
- Girders: 3 hours
- Floors, Roofs, Intermediate Beams and Corridor Ceilings: 2 hours

Architects: Hertzka & Knowles, San Francisco
Skidmore, Owings & Merrill

Structural Engineer: H. J. Brunnier, San Francisco





An unusual combination of membrane and contact fireproofing protects the new Crown Zellerbach Building in San Francisco, California. Hertzka & Knowles and Skidmore, Owings & Merrill, Associated Architects, and H. J. Brunnier, Structural Engineer, have effectively blended the old and the new in lightweight fire protection.

Flexibility is the keynote of this west coast landmark. Supported by two rows of steel columns, 63 feet apart, each office floor is divided into 5½-foot modules. Each module is served by its own lighting and air conditioning vents. A light gauge cellular steel floor permits electrical service to be provided anywhere on the floor.

The San Francisco Building Code requires 2-hour fire protection for floors and secondary beams, and in addition, for all corridor ceilings. This could have been provided by a suspended membrane plaster ceiling. Instead, the designers chose to protect the structural members individually with lightweight vermiculite-gypsum plaster and the floor decking with acoustic plaster. A suspended plaster ceiling was provided, but could not be considered as contributing to the fire resistance of the structural floor system because large lighting units pierced the ceiling at frequent intervals. However, with the addition of a special insulating cover over the lighting fixtures, 2-hour fire protection was provided at corridor ceilings.

The decision to use contact fireproofing and individual protection of the structural components rather than a suspended ceiling to attain the required fire rating was influenced by these important factors:

1. Design of the duct work was not hampered by code restrictions on openings through a membrane ceiling.
2. Acoustic plaster sprayed directly to the underside of the cellular steel floor was found to be the most economical form of fireproofing for the floor framing design employed.
3. Future alterations to the duct system will be less expensive since the contact fireproofing is above the mechanical equipment.
4. Corridors can be placed anywhere in the building and the 2-hour ceiling protection required by the San Francisco building code will be economically obtained by adding the special cover of insulating material over the lighting fixtures in the suspended ceiling.

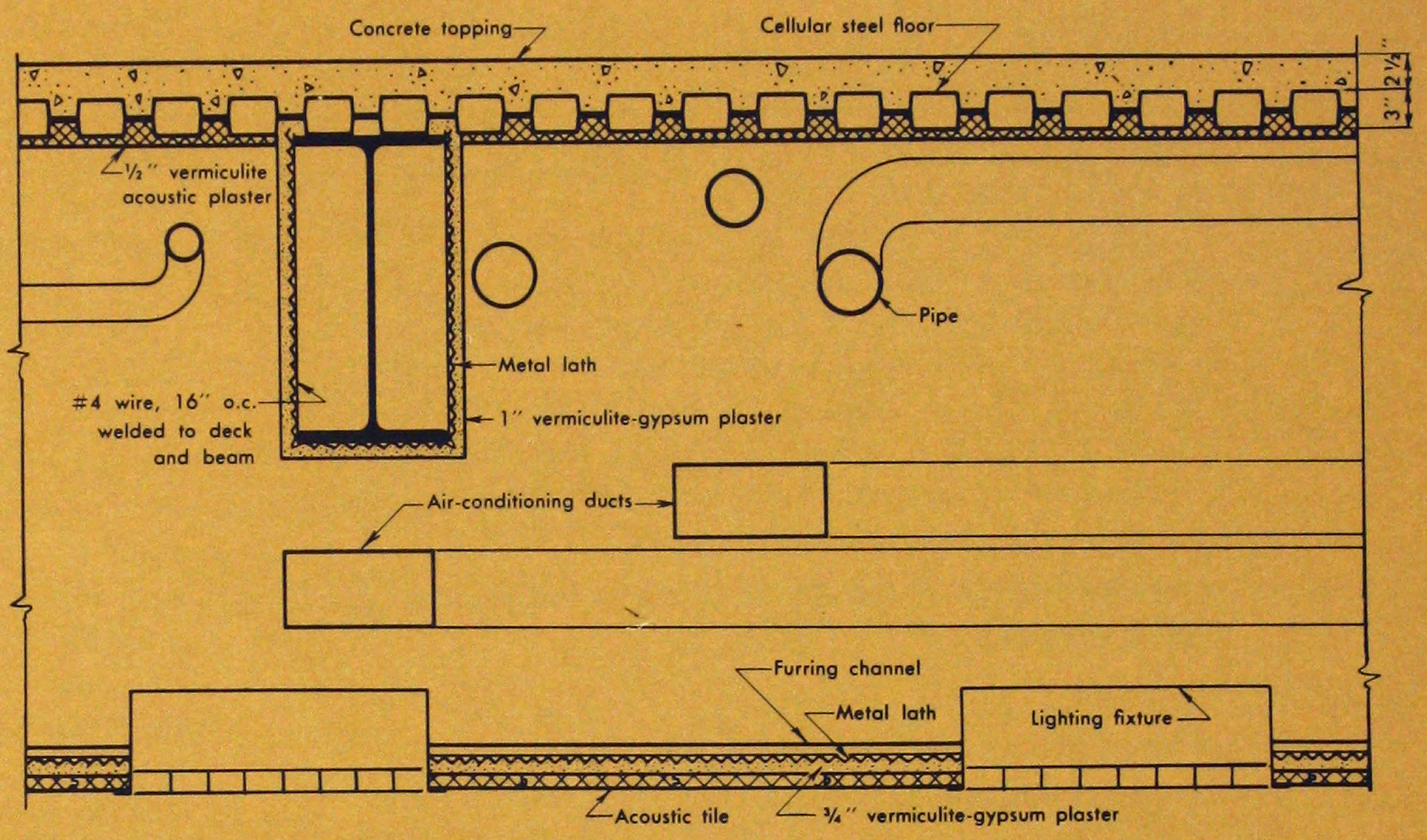
The unusual Crown Zellerbach Building demonstrates the inherent flexibility of fire-resistant steel construction and the high degree of freedom of design which this form of construction permits the architect and engineer.

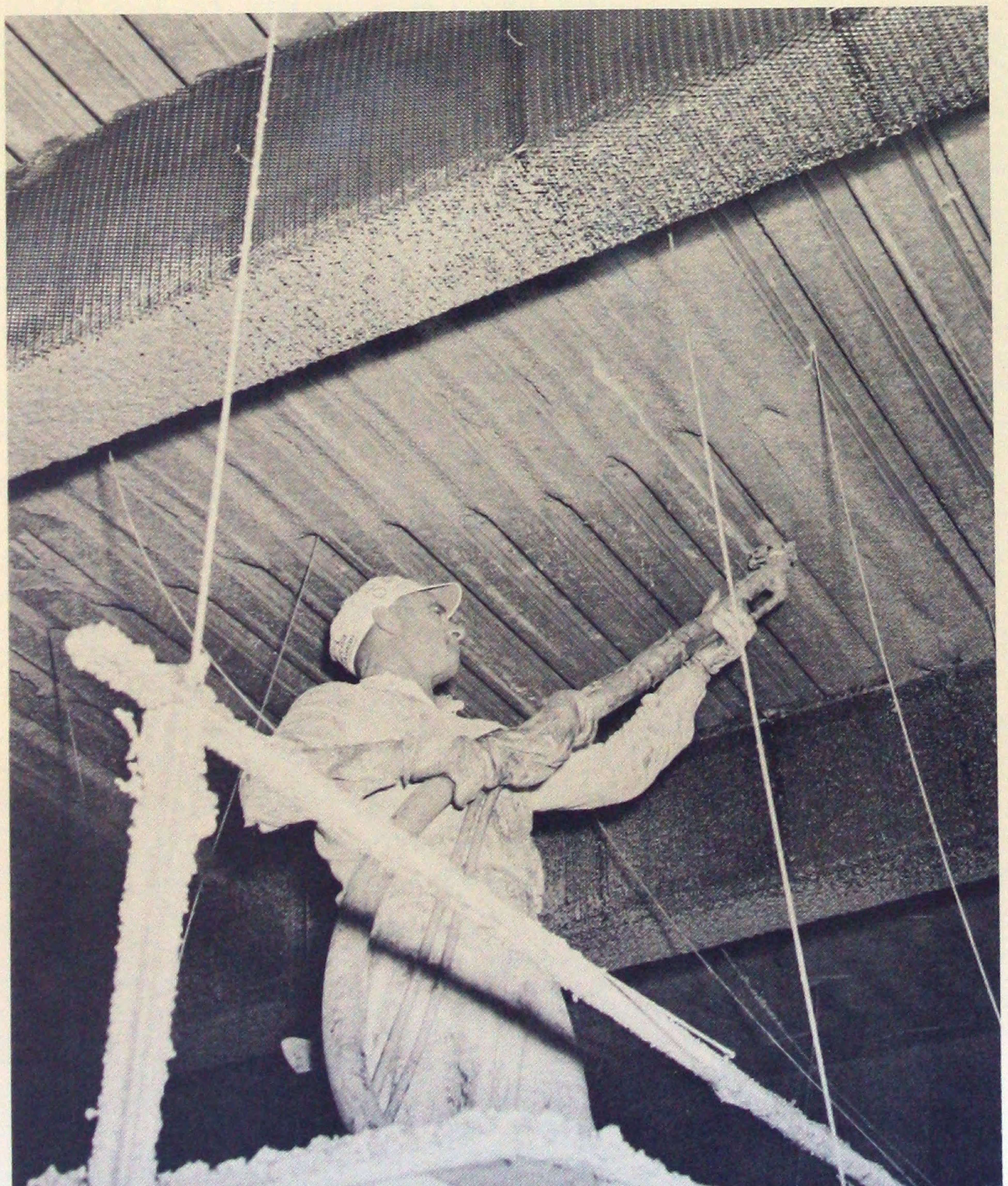
'Most Exciting Building"

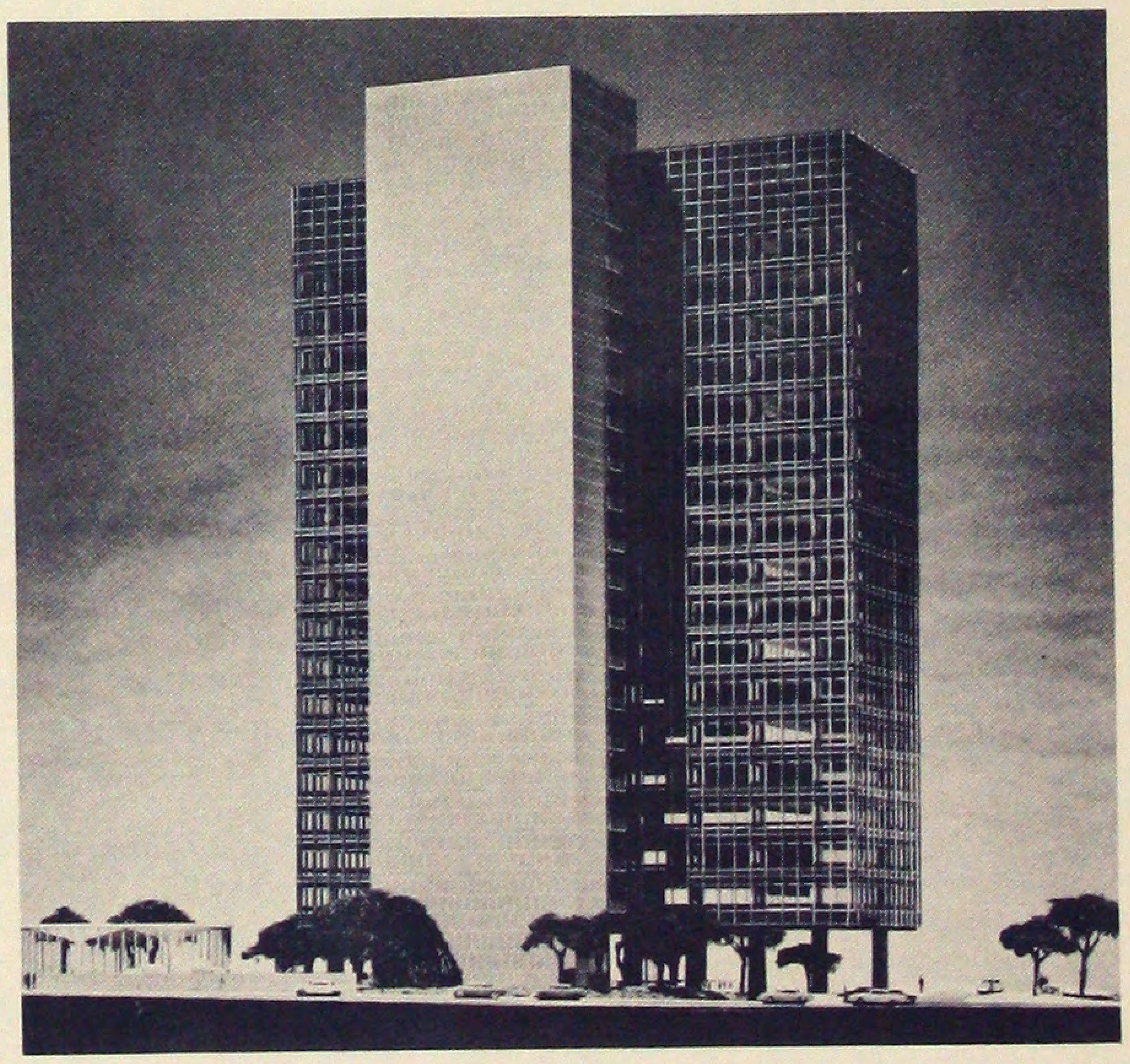
Plaster fireproofing permits use of column flange space for telephone lines and cabinets.

Contact acoustic plaster fireproofing for the cellular steel floor — individual lath and plaster protection for beams and girders. The suspended plaster ceiling with applied acoustic tile is pierced by rows of lighting fixtures and is not considered fire-resistant.

Use of a special cover of insulation over lighting fixtures in corridors permits plaster ceiling to achieve 2-hour fire resistance rating. The acoustic tile does not significantly increase the fire resistance of the assembly.







San Francisco's new Crown Zellerbach Building office tower is encased in heat absorbing glass curtain walls.

Application of acoustic plaster to underside of cellular steel floor. Flutes of decking are filled before specified thickness is applied.

Fire Resistance Ratings

THE TABLES of fire resistance ratings which follow are based upon standard fire tests made in accordance with the "Standard Methods of Fire Tests of Building Construction and Materials", ASTM E 119. In each case the testing agency is noted, as is the test reference. The designer may consult the original test data for additional information if desired.

An exception is made in the case of concrete fireproofing of columns, beams and girders, for which some estimated ratings are listed. These have been selected by leading code authorities from a wealth of published ratings based on standard fire test data dealing with various minimum coverages and many types of concrete aggregate. They are acceptable to most building code authorities.

Ratings are listed for the following categories in the order shown:

Columns

Beams, girders, and trusses

a. Individually fireproofed
b. Fire-protected by membrane ceiling

Floor and Roof Systems

a. Light gauge steel systems—membrane fireproofed
b. Light gauge steel systems—contact fireproofed
c. Light gauge steel systems—not fireproofed
d. Precast concrete cellular systems—not fireproofed
e. Joist and slab systems (open-web or solid-web steel joists)—membrane fireproofed
f. Reinforced concrete slabs—not fireproofed
g. Reinforced concrete slabs—membrane fireproofed

Wall and partition fire resistance ratings are not included because of space limitations.

Following the practice of many building codes, the following hourly rates are listed:

Columns: 1, 2, 3 and 4 hours

Beams, Girders, Trusses: 1, 1½, 2, 2½, 3 and 4 hours

Floors and Roofs: 1, 1½, 2, 2½, 3 and 4 hours

Several of the 4-hour ratings shown in the tables are based on tests which have been conducted for 5 hours or more without reaching critical limits. These are identified with an asterisk (*).

Some modifications, based upon interpolation of test data, are acceptable to most code authorities:

a. Fire-resistant constructions shown for columns are conservative when assigned the same rating for use in protecting beams or girders.

b. Most authorities agree with the National Board of Fire Underwriters that in general, "a facing of ¾-inch portland-cement or (sand-) gypsum plaster will usually increase the fire resistance of a 1-hour assembly by ½-hour. On 2-, 3-, and 4-hour assemblies the increase for the same kind and thickness of plaster will be progressively greater, amounting usually to about 1-hour on a 4-hour assembly."

c. The use of perlite or vermiculite aggregate in place of sand in plaster considerably increases the fire resistance of any assembly. Although no definitive study has been made of the relative fire-resistive properties of vermiculite and perlite aggregates mixed in the same proportions in gypsum plaster, many of the tests indicate that these materials may be substituted for each other to achieve the same fire resistance rating.

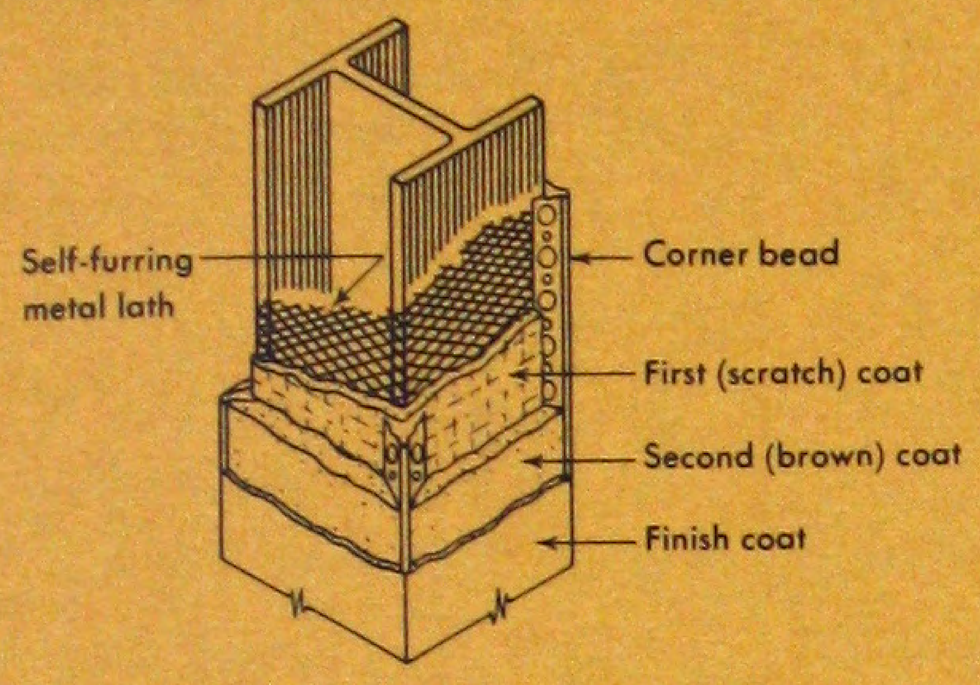
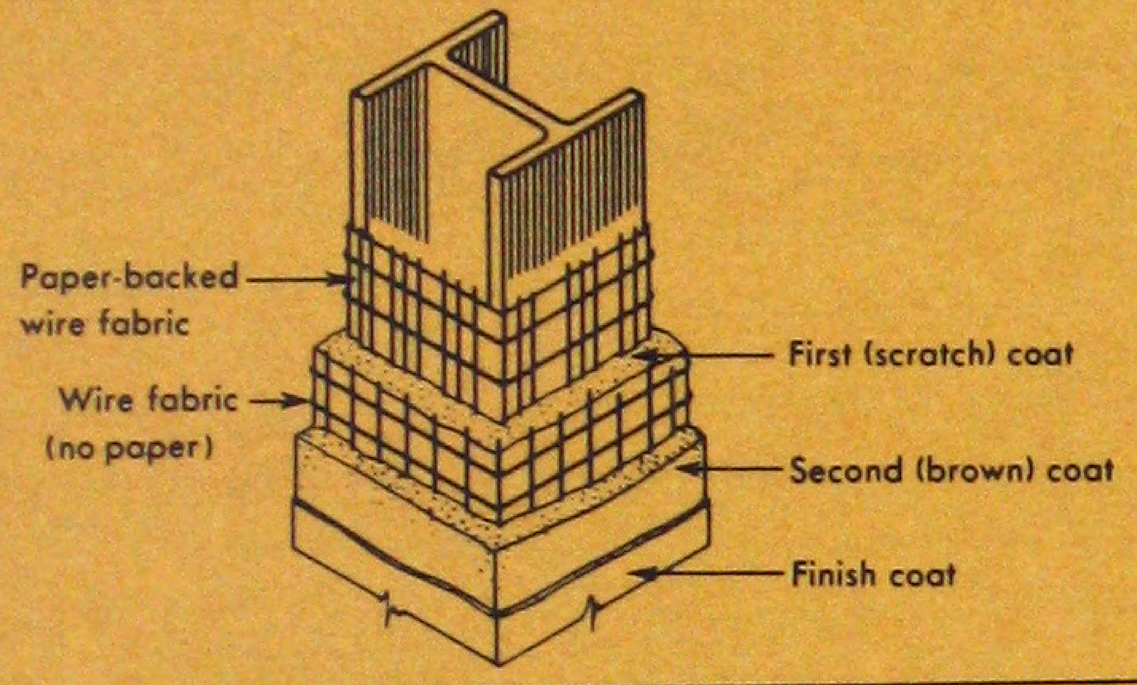
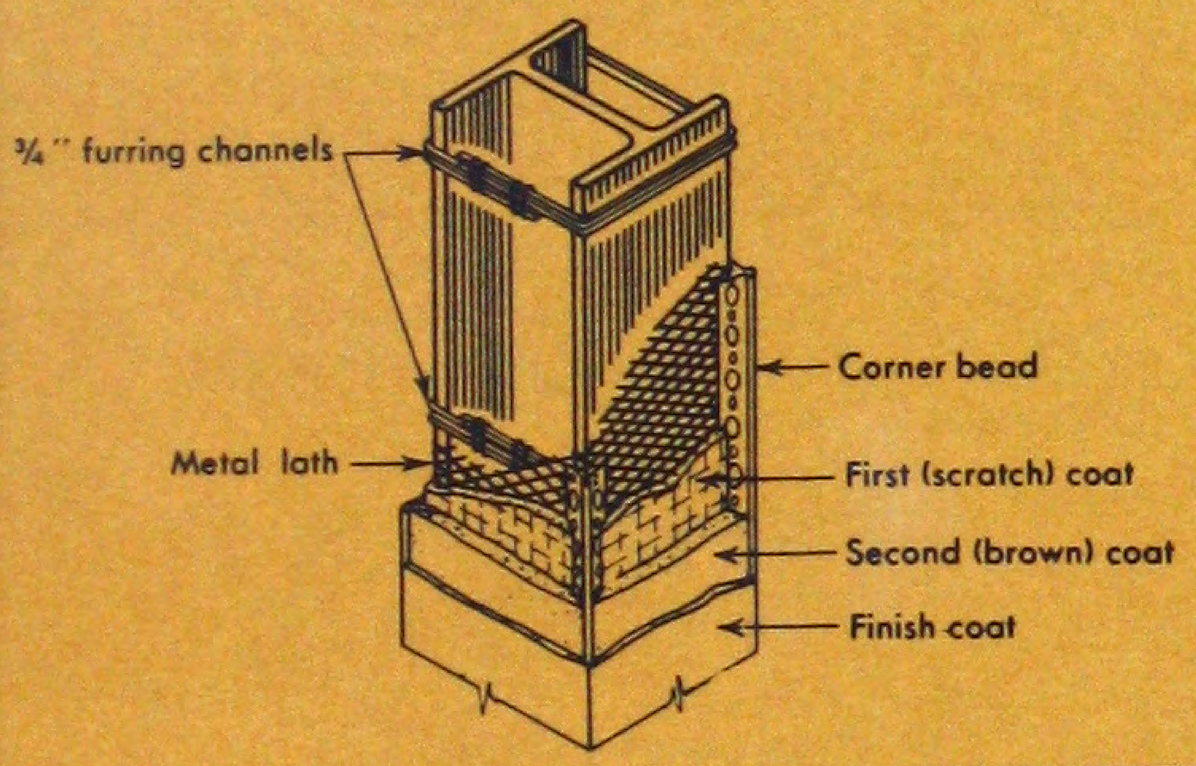
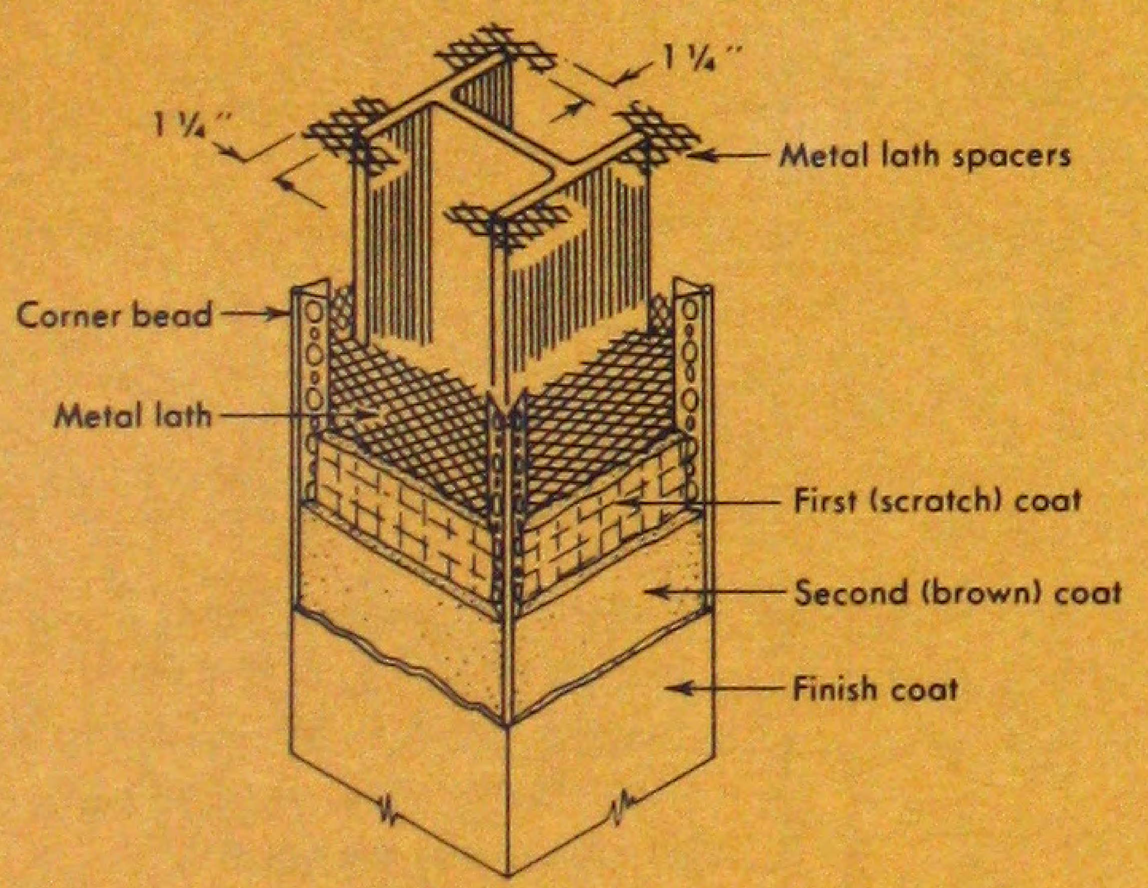
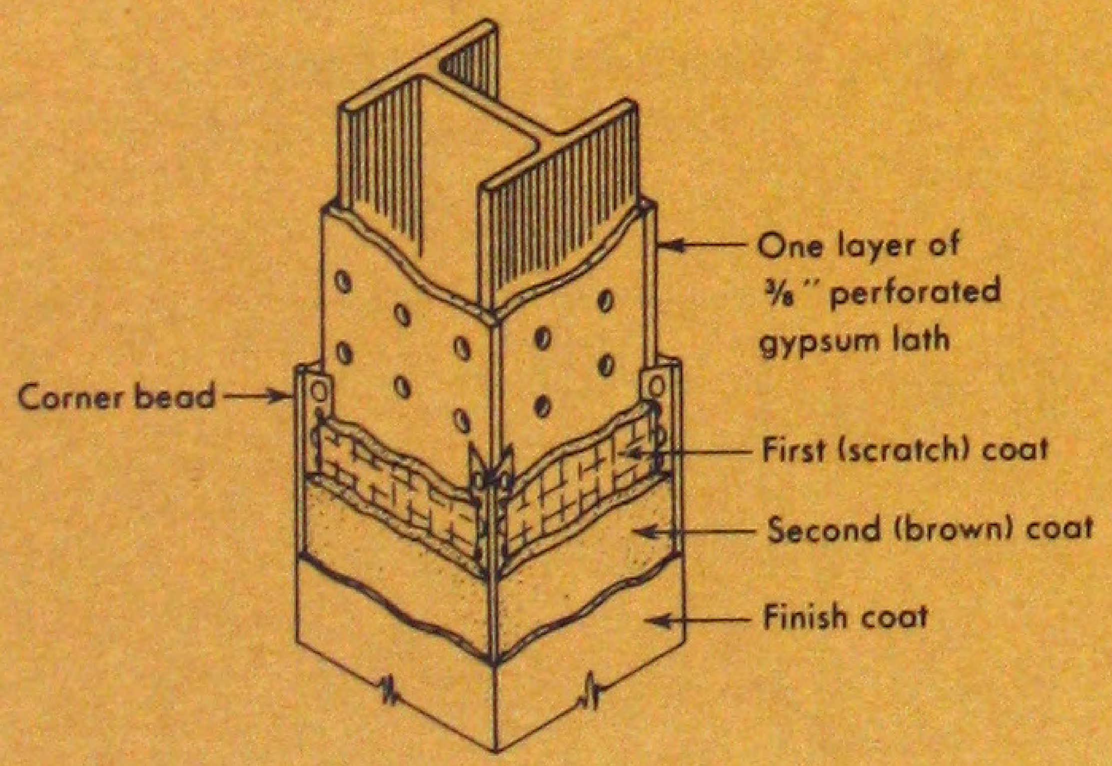
d. Tests of membrane ceiling protections indicate that one electrical outlet box, 16 square inches in area, may be installed in each 90 square feet of ceiling area without affecting the fire resistance of the ceiling. The effect of larger openings in fire-resistant ceilings is less clearly defined. In the tables that follow, the actual openings tested are designated as the maximum for the listed fire resistance ratings. However, some authorities permit any fire-resistant ceiling to be pierced by duct openings up to 100 square inches in each 100 square feet of ceiling area without changing the rating—provided each duct is protected by a 160°F fusible-link damper which will automatically seal off the opening in the presence of fire.

Thickness of plaster is measured from face of lath. Total thickness called for in the tables includes both scratch and brown coats. The usual 1/16-inch white or finish coat of plaster may be included in the required thickness of plaster.

Weights and types of metal lath are listed in footnotes. All lath work should be in conformity with the "American Standard Specifications for Interior Lathing and Furring", ASA 42.4—1955. Unless otherwise indicated, all plastering should be in conformity with either the "Standard Specifications for Gypsum Plastering", ASA 42.1—1955, or the "Standard Specifications for Portland Cement Plastering", ASA 42.3—1946. In all cases ratings depend upon the fire protection being securely attached to structural components, so that it will remain in place during fire exposure.

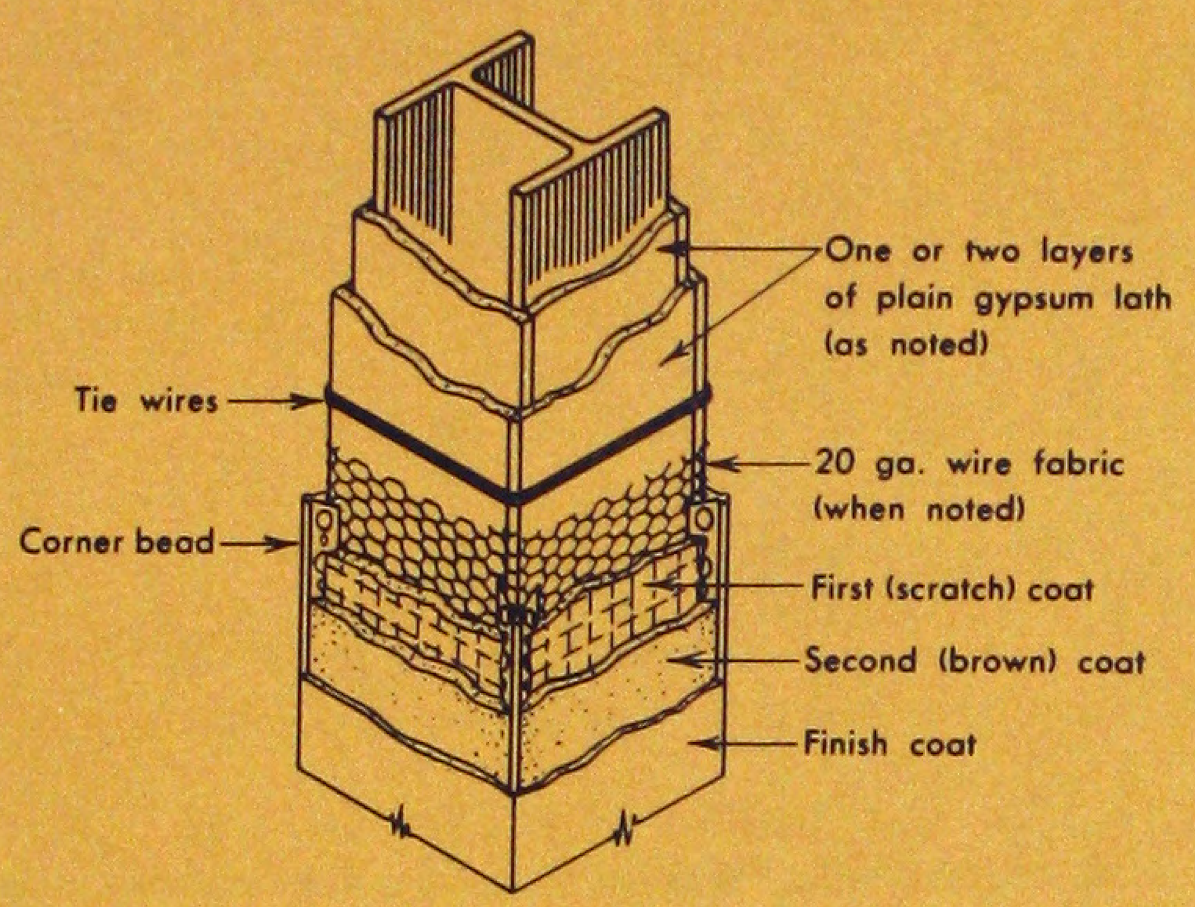
In floor constructions the critical point of the fire tests has often been reached when the temperature rise on the top (unexposed) surface of the floor exceeded the allowable limit. For this reason the thickness of the concrete top fill or slab and the selection of aggregate are important factors in the fire-resistant value of the floor construction. Modifications should be carefully evaluated.

Columns

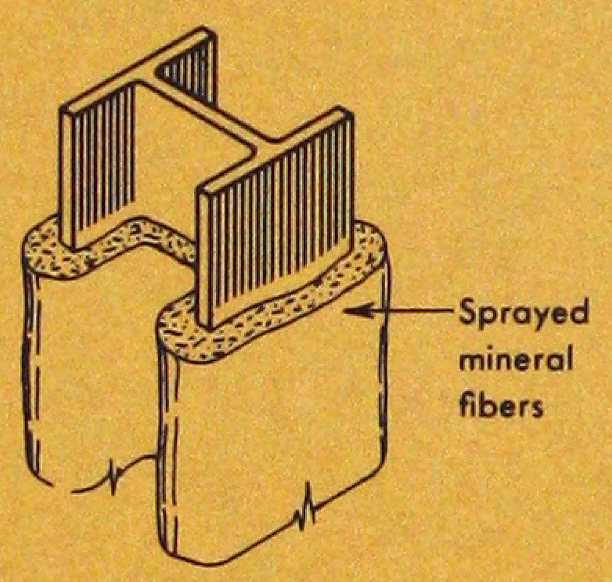
Drawing	No.	Description	Rating (Hours)	Authority [1]
	1	1¾" vermiculite- or perlite-gypsum plaster [2] on self-furring metal lath.[3]	4	Underwriters' Lab., Inc. Ret. 3187-4 (Design 6-4 hr.) Ret. 2851-6 (Design 9-4 hr.)
	2	1⅜" vermiculite- or perlite-gypsum plaster [2] on self-furring metal lath.[3]	3	Underwriters' Lab., Inc. Ret. 3187-7 (Design 6-3 hr.) Ret. 2851-5 (Design 8-3 hr.)
	3	1" perlite-gypsum plaster [2] on self-furring metal lath.[3]	2	Underwriters' Lab., Inc. Ret. 3187-5 (Design 2-2 hr.)
	4	2" vermiculite-portland cement plaster [4] on paper-backed wire fabric,[5] with an additional layer of wire fabric (no paper) [6] over scratch coat.	4	Underwriters' Lab., Inc. Ret. 3653-3 (Design 10-4 hr.)
	5	Same as No. 4 above, except: 2⅛" perlite-portland cement plaster.[7]	4	Underwriters' Lab., Inc. Ret. 3329-2 (Design 8-4 hr.)
	6	1½" perlite-gypsum plaster [2] on metal lath [8] spaced from column flanges by ¾" steel furring channels. No back fill plaster required between metal lath and column flanges.	4	Underwriters' Lab., Inc. Ret. 3187-6 (Design 7-4 hr.)
	7	Same as No. 6 above, except: ¾" sand-gypsum plaster [9] **or** 1" portland cement plaster [10] on metal lath.[11]	1	Nat'l Bureau of Standards BMS 92—Table 40
	8	1½" vermiculite- or perlite-gypsum plaster [2] on metal lath.[8] Lath spaced 1¼" from column flanges. Space behind lath on flange faces filled with plaster.	4	Underwriters' Lab., Inc. Ret. 2851-2 (Design 1-4 hr.) Ret. 3187-3 (Design 2-4 hr.)
	9	Same as No. 8 above, except: 1" vermiculite- or perlite-gypsum plaster.[2]	3	Underwriters' Lab., Inc. Ret. 2851-1 (Design 1-3 hr.) Ret. 3187-1 (Design 3-3 hr.)
	10	Same as No. 8 above, except: 1½" vermiculite-gypsum plaster [2] with **no** plaster fill behind lath.	3	Underwriters' Lab., Inc. Ret. 3422-2 (Design 9-3 hr.)
	11	Same as No. 8 above, except: 1" perlite-gypsum plaster [2] with **no** plaster fill behind lath.	2	Underwriters' Lab., Inc. Ret. 3187-2 (Design 1-2 hr.)
	12	1⅜" perlite-gypsum plaster [2] **or** 2" sand-gypsum plaster [12] on one (1) layer of ⅜" perforated gypsum lath.	3	Nat'l Bureau of Standards Test 321 and Test 344
	13	1" perlite-gypsum plaster [2] **or** 1⅜" sand-gypsum plaster [12] on one (1) layer of ⅜" perforated gypsum lath.	2	Nat'l Bureau of Standards BMS 135—Test 275 Test 351
	14	½" sand-gypsum plaster [13] on one (1) layer of ⅜" perforated gypsum lath.	1	Nat'l Bureau of Standards BMS 135—Test 273

Note: Superior numbers refer to notes on page 40.

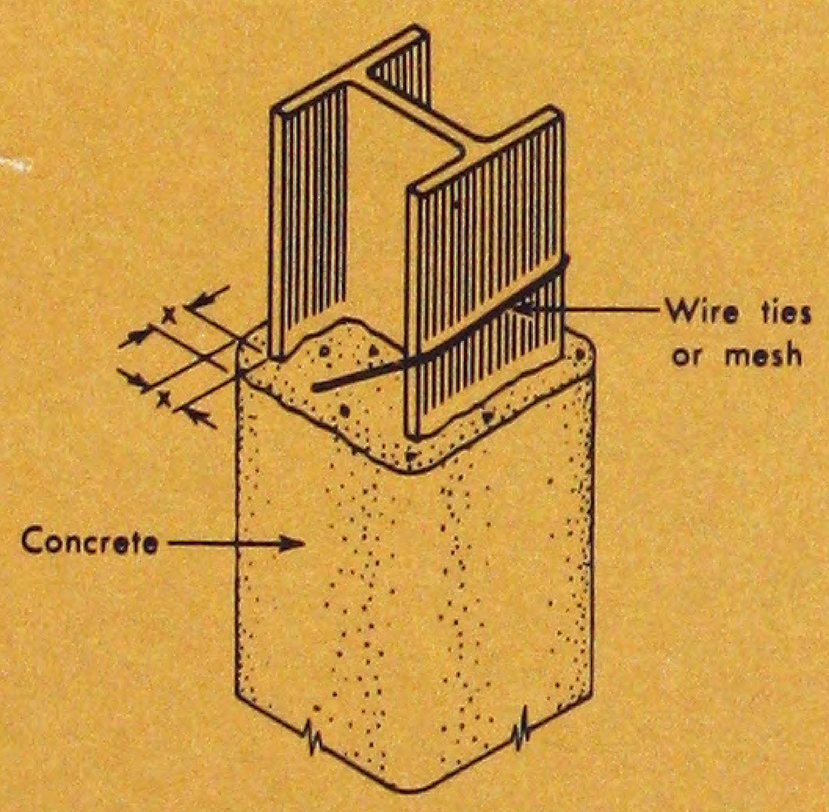
Columns (cont.)



No.	Description	Rating (Hours)	Authority [1]
15	1½" perlite- or vermiculite-gypsum plaster [2] on two (2) layers of ½" thick plain gypsum lath wrapped with one (1) layer of 20 ga. wire mesh fabric, 1" mesh (poultry netting).	4	Nat'l Bureau of Standards BMS 135—Tests 278, 279, 280, 294
16	2⅛" (⅝" scratch coat and 1½" brown coat) perlite-gypsum plaster [14] on one (1) layer of ½" thick plain gypsum lath. 17 ga. wire mesh fabric, 1" mesh (poultry netting) over scratch coat; **no** fabric over lath.	4	Underwriters' Lab., Inc. Ret. 3329-1 (Design 4-4 hr.)
17	1½" (¾" scratch coat and ¾" brown coat) perlite-gypsum plaster [2] on one (1) layer of ½" thick plain gypsum lath. One (1) layer of 20 ga. wire mesh fabric, 1" mesh (poultry netting) over scratch coat; **no** fabric over lath.	3	Nat'l Bureau of Standards BMS 135—Test 277
18	Same as No. 15 above, except: 1" perlite-gypsum plaster.[2]	3	Nat'l Bureau of Standards BMS 135—Test 276
19	1⅜" perlite-gypsum plaster [2] on two (2) layers of ½" thick plain gypsum lath; no fabric over scratch coat or lath.	3	Nat'l Bureau of Standards BMS 135—Tests 289, 293



No.	Description	Rating (Hours)	Authority [1]
20	2½" sprayed mineral fibers [15] applied directly to column coated with special adhesive.	4*	Underwriters' Lab., Inc. Ret. 3749-4 (Design 11-5 hr.)
21	2" sprayed mineral fibers [15] applied directly to column coated with special adhesive.	3	Underwriters' Lab., Inc. Ret. 3705-2 (Design 7-3 hr.)
22	1½" sprayed mineral fibers [15] applied directly to column coated with special adhesive.	2	Underwriters' Lab., Inc. Ret. 3705-3 (Design 4-2 hr.)



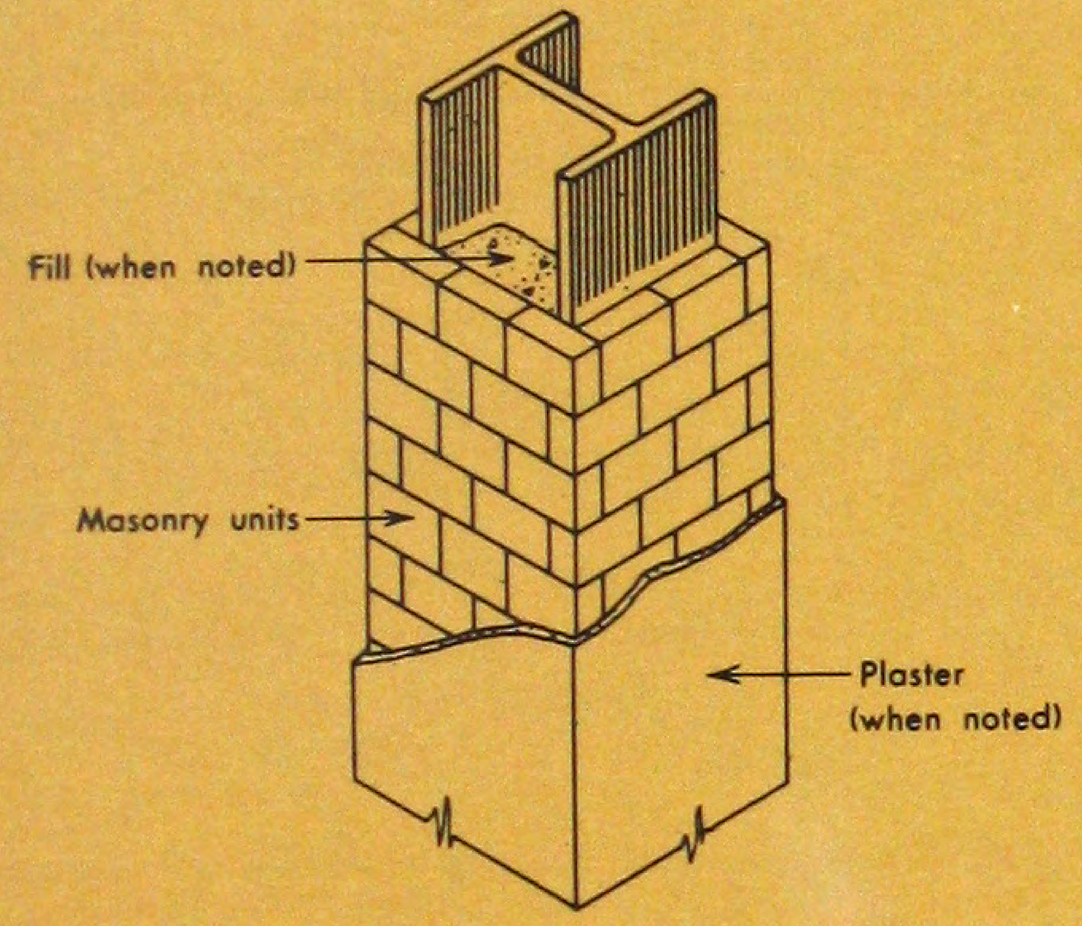
No.	Description	Rating (Hours)	Authority [1]
23	Concrete encasement: Grade "A" concrete.[16] x = 2" x = 1½" x = 1"	4, 3 2 1	Nat'l Bureau of Standards** BMS 92—Table 39 TP 184 **Listed ratings are **not** tested ratings, but are based on the results of standard tests described in these references.[19]
24	Concrete encasement: Grade "B" concrete.[17] x = 2½" x = 2" x = 1½"	4 3 2, 1	(as above)
25	Concrete encasement: Grade "C" concrete.[18] x = 3" x = 2½" x = 2" x = 1½"	4 3 2 1	(as above)
26	Gypsum concrete encasement; 4" x 4" wire mesh reinforcement wrapped around column. x = 2"	4[20]	Nat'l Bureau of Standards Research Paper No. RP563

(See drawing, top of page 29)

No.	Description	Rating (Hours)	Authority [1]
27	Brick; 3¾" thick; reentrant spaces filled with brick and mortar. No plaster.	4*	Nat'l Bureau of Standards BMS 92—Table 40
28	Same as No. 27 above, except: 2¼" thick.	1	Nat'l Bureau of Standards BMS 92—Table 40

Note: Superior numbers refer to notes on page 40.

Asterisks (*) identify tests conducted 5 hours or more without reaching critical limits.

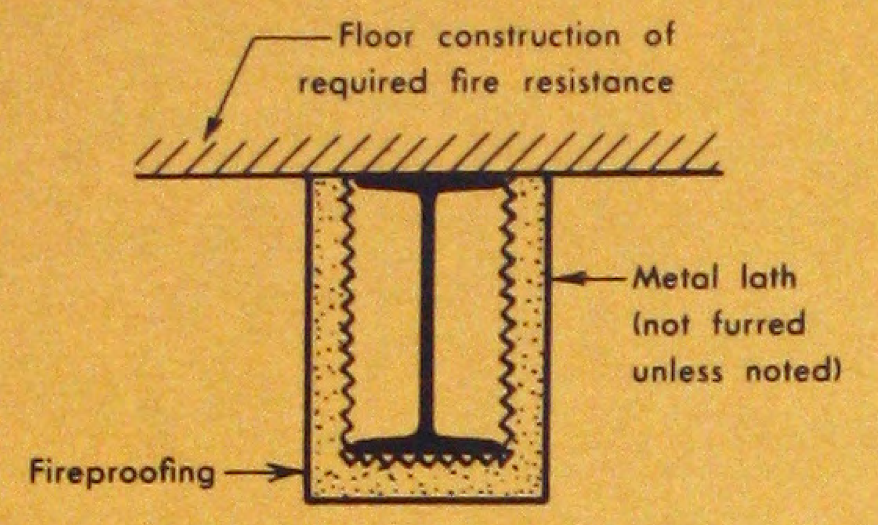


Drawing	No.	Description	Rating (Hours)	Authority [1]
	29	2" gypsum block, solid, plus ½" sand-gypsum plaster.[9] Cramps at horizontal joints. Mortar on flange only at horizontal joints. No fill. Minimum area of solid material to be 105 sq. inches.	4	Nat'l Bureau of Standards BMS 92—Table 40
	30	Same as No. 29 above, except: 3" gypsum block, hollow, plus ½" sand-gypsum plaster.[9] Minimum area of solid material to be 120 sq. inches.	4*	
	31	Same as No. 29 above, except: No plaster. Minimum area of solid material to be 85 sq. inches.	2	
	32	Same as No. 30 above, except: No plaster. Minimum area of solid material to be 95 sq. inches.	2	
	33	2", 3" or 4" hollow clay or shale tile; reentrant spaces filled with concrete. Wire mesh in horizontal joints; Mortar between tile and column flanges. No plaster. Minimum area of solid material to be 225 sq. inches.	4	
	34	4" hollow clay tile in two 2" layers; Mortar between tile and column flanges. Wire mesh in horizontal joints. Reentrant spaces filled with tile and mortar. No plaster. Minimum area of solid material to be 250 sq. inches.	4	
	35	Same as No. 33 above, except: Minimum area of solid material to be 180 sq. inches.	3	
	36	Same as No. 33 above, except: Minimum area of solid material to be 110 sq. inches.	2	
	37	Same as No. 33 above, except: Reentrant spaces not filled. Minimum area of solid material to be 70 sq. inches.	1	
	38	3" cinder block, hollow. Reentrant spaces filled with block and mortar. No plaster. Minimum area of solid material to be 240 sq. inches.	4[21]	

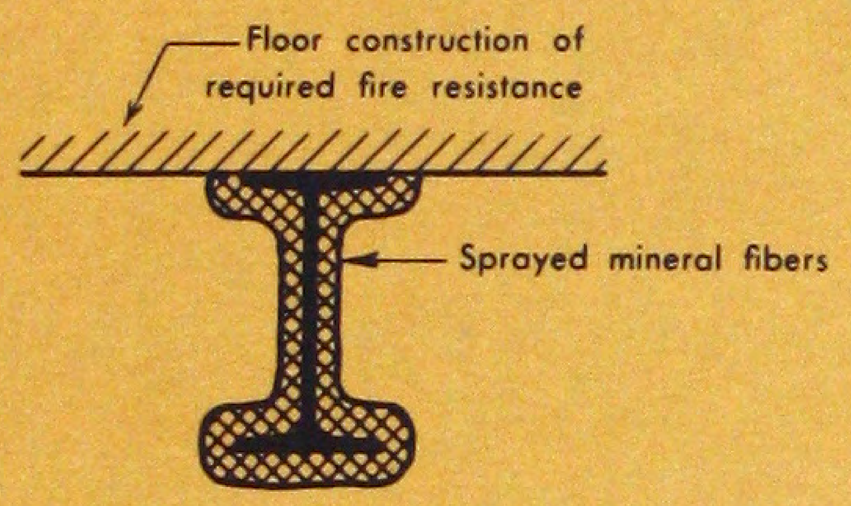
Beams, Girders and Trusses: Individually Fireproofed

Drawing	No.	Description	Rating (Hours)	Authority
(See drawing, top of page 30)	39	1½" vermiculite- or perlite-gypsum plaster[2] on self-furring metal lath.[3]	4*[22]	Underwriters' Lab., Inc. Ret. 2689-5 (Design 19-4 hr.) Ret. 3413-4 (Design 8-4 hr.) Ret. 4197-1
	40	1⅛" vermiculite-gypsum plaster[2] on flat expanded metal lath[8] furred from flanges by ¾" furring channels.	4	Underwriters' Lab., Inc. Ret. 3372-3 (Design 16-4 hr.)
	41	1¼" perlite-gypsum plaster[2] on flat expanded metal lath.[8]	3	Underwriters' Lab., Inc. Ret. 4197-1

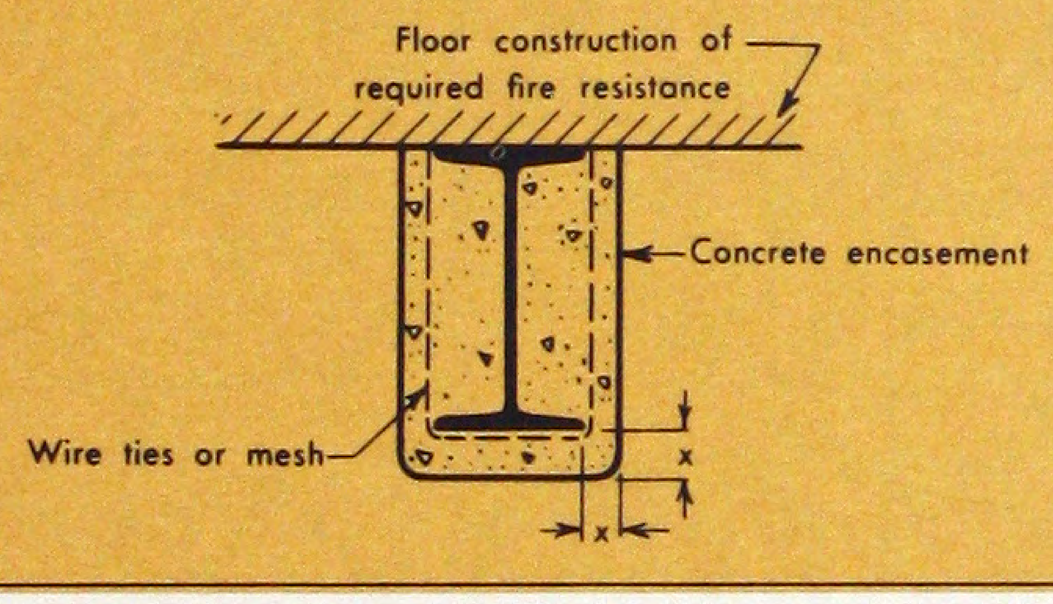
Beams, Girders and Trusses: Individually Fireproofed (cont.)



No.	Description	Rating (Hours)	Authority[1]
42	1" vermiculite-gypsum plaster[2] on flat expanded metal lath.[8]	2½[23]	Underwriters' Lab., Inc. Ret. 3413-10 (Design 3-2 hr.)
43	Same as No. 42 above, except: ⅞" vermiculite-gypsum plaster.[2]	2	Underwriters' Lab., Inc. Ret. 3413-9 (Design 7-3 hr.)
44	2" vermiculite or perlite acoustic plaster[15] on self-furring metal lath,[3] or flat expanded metal lath.[8]	4	Underwriters' Lab., Inc. Ret. 3413-7 (Design 10-4 hr.) Ret. 3983-1
45	1¾" perlite acoustic plaster[15] on flat expanded metal lath.[8]	3	Underwriters' Lab., Inc. Ret. 3413-11 (Design 7-2 hr.)
46	Sprayed mineral fibers,[15] 1¼" thick on sides of beam, 1½" thick below beam on ribbed metal lath.[24] No adhesive.	4*	Underwriters' Lab., Inc. Ret. 3705-3 (Design 20-4 hr.)

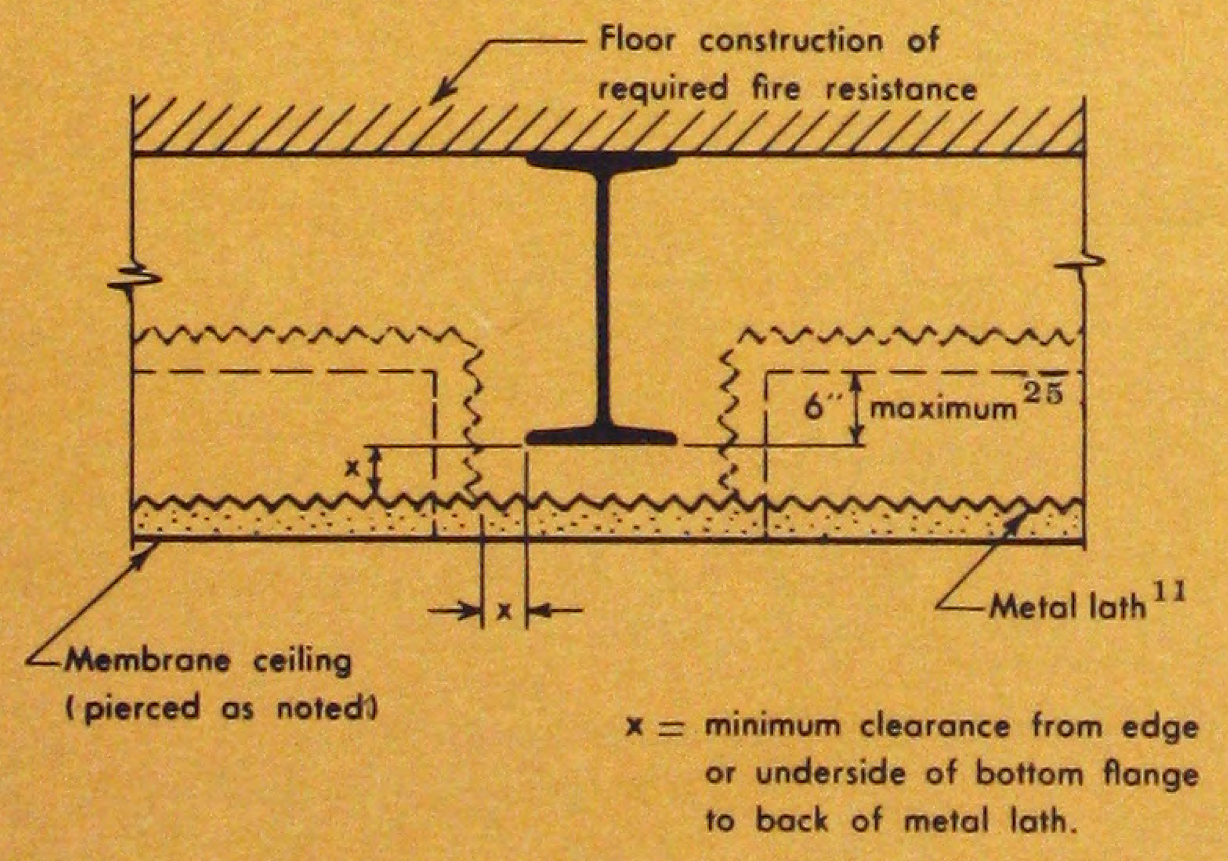


No.	Description	Rating (Hours)	Authority[1]
47	1⅞" sprayed mineral fibers[15] applied directly to beam coated with special adhesive.	4	Underwriters' Lab., Inc. Ret. 2923-4
48	1 7/16" sprayed mineral fibers[15] applied directly to beam coated with special adhesive.	3	Underwriters' Lab. of Canada Ret. 193-2 (Design C9-3 hr.)
49	1⅛" sprayed mineral fibers[15] applied directly to beam coated with special adhesive.	2	Underwriters' Lab. of Canada Ret. 193-3



No.	Description	Rating (Hours)	Authority[1]
50	Concrete encasement: Use same ratings and constructions designated for column protections in Fire Resistance Ratings Nos. 23, 24 and 25 listed on page 28.	4,3,2,1	Estimated ratings based on column tests.

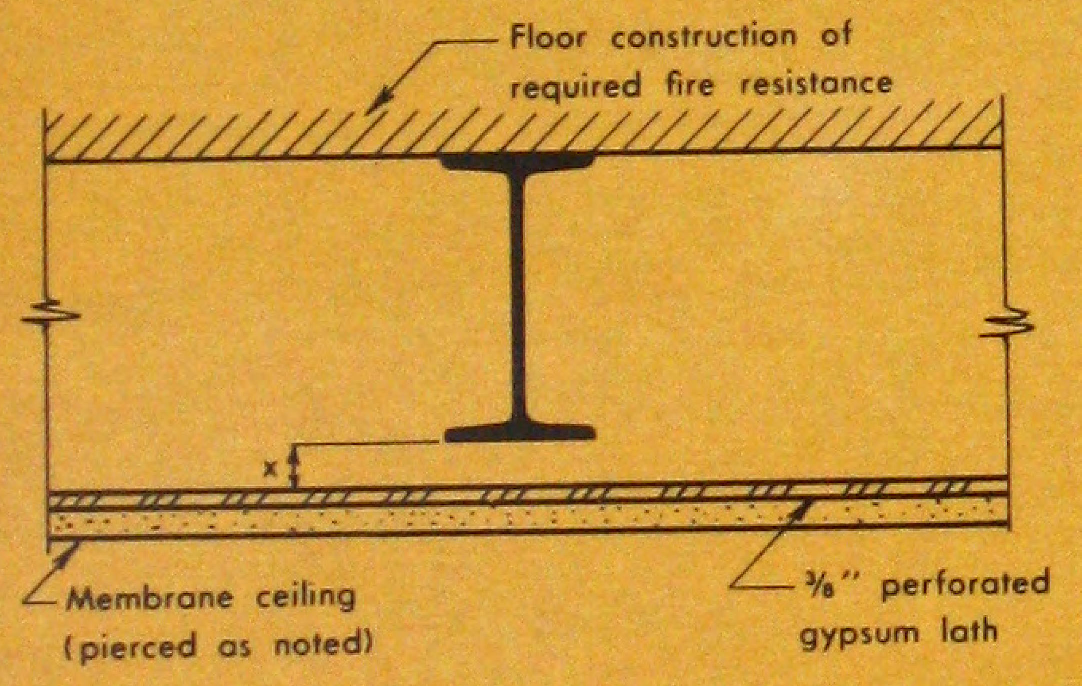
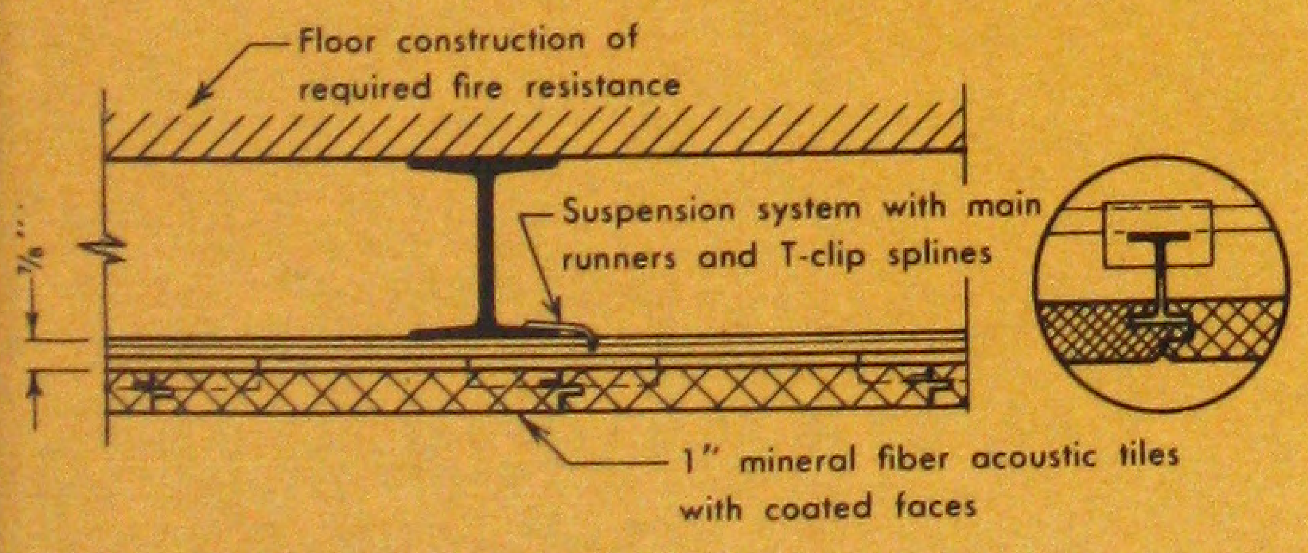
Beams, Girders and Trusses: Fire-protected by a Membrane Ceiling



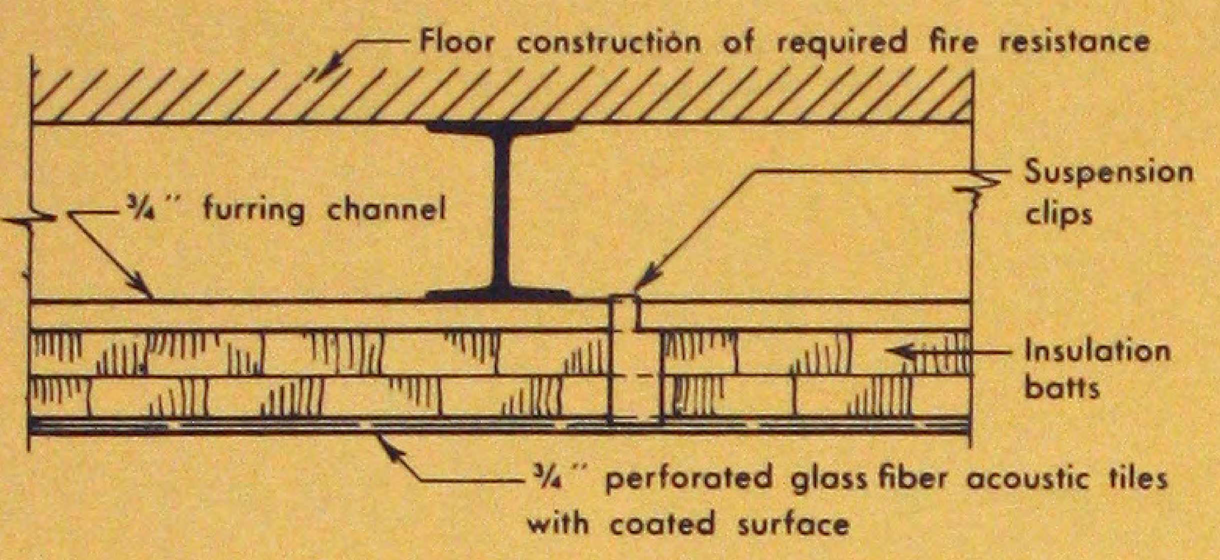
No.	Description	Rating (Hours)	Authority[1]
51	1" vermiculite-gypsum plaster.[26] x = 0"	4	Nat'l Bureau of Standards BMS 92—Table 43
52	⅞" perlite-gypsum plaster.[2] x = 2¾" Note: Ceiling pierced with duct openings (70 sq. inches in each 100 sq. feet of ceiling area) and electrical outlets (one in each 90 sq. feet of ceiling area). Duct openings protected with fusible link dampers.	4	Underwriters' Lab., Inc. Ret. 3724-1 (Design 8-3 hr.)
53	¾" perlite-gypsum plaster.[2] x = 3½" Note: Ceiling pierced same as No. 52 above, except duct openings 113 sq. inches in each 100 sq. feet of ceiling area.	4	Underwriters' Lab., Inc. Ret. 3574-6 (Design 11-3 hr.)
54	⅝" vermiculite-gypsum plaster[2] base plus ½" finish vermiculite acoustic plaster.[15] (Total thickness 1⅛" over face of lath). x = 2½"	4	Underwriters' Lab., Inc. Ret. 2773-5 (Design 4-4 hr.)

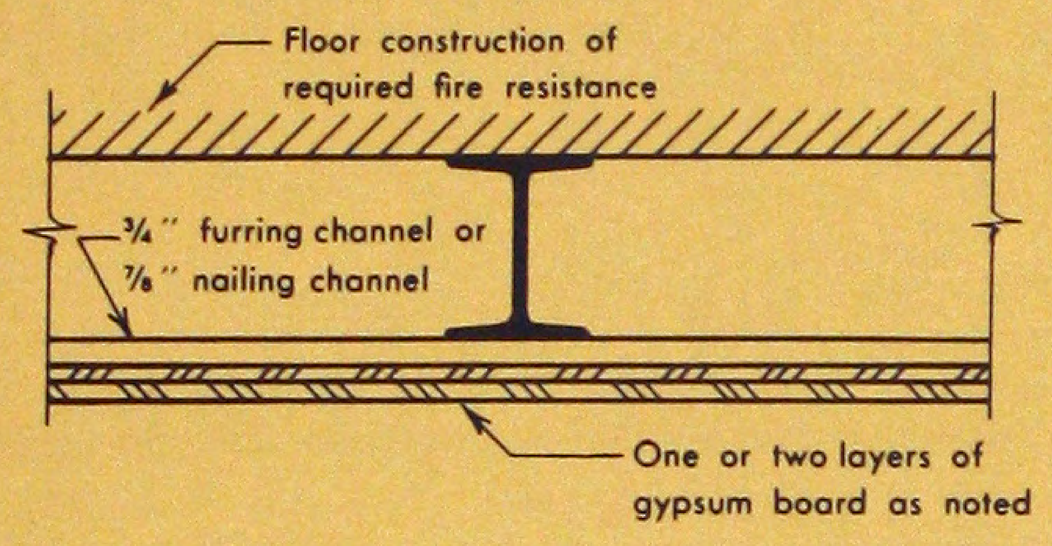
Note: Superior numbers refer to notes on page 40.

Asterisks (*) identify tests conducted 5 hours or more without reaching critical limits.

Drawing	No.	Description	Rating (Hours)	Authority [1]
(See drawing, bottom of page 30)	55	7/8" vermiculite-gypsum plaster.[2] x = 3 1/2" Note: Ceiling pierced same as No. 52 above, except duct openings 85 sq. inches in each 100 sq. feet of ceiling area.	3	Underwriters' Lab., Inc. Ret. 2689 (Design 1-3 hr.)
	56	3/4" vermiculite-gypsum plaster.[26] x = 0"	3	Nat'l Bureau of Standards BMS 92—Tables 43 and 44 TRBM 44—Tables 18 and 22
	57	1" neat wood-fibered gypsum plaster. x = 0"	3	
	58	1 1/8" sand-gypsum plaster.[27] x = 0"	3	
	59	1 1/2" sand-gypsum plaster.[28] x = 0"	2 1/2	
	60	1" sprayed asbestos fibers.[15] x = 0"	2 1/2	
	61	3/4" sand-gypsum plaster.[12] x = 0"	2	
	62	1" sand-portland cement plaster.[29] x = 0"	2	
	63	3/4" sprayed asbestos fibers.[15] x = 0"	2	
	64	3/4" sand-portland cement plaster with asbestos fibers added.[30] x = 0"	1 1/2	
	65	5/8" sprayed asbestos fibers.[15] x = 0"	1 1/2	
	66	1/2" perlite-gypsum plaster,[2] reinforced with 1" hexagonal wire mesh stretched under lath. x = 3/4"	4*	Nat'l Bureau of Standards BMS 141—Test 312
	67	5/8" perlite-gypsum plaster,[2] reinforced with No. 14 ga. wires secured below lath on the diagonal, corner to corner of lath. x = 3/4"	4	Nat'l Bureau of Standards BMS 141—Test 313
	68	1/2" perlite-gypsum plaster,[2] reinforced with No. 14 ga. wires secured below lath on the diagonal, corner to corner of lath. x = 3/4"	2 1/2	Nat'l Bureau of Standards BMS 141—Test 318
	69	5/8" sand-gypsum plaster,[12] reinforced with No. 14 ga. wires secured below lath on the diagonal, corner to corner of lath. x = 3/4"	1 1/2	Nat'l Bureau of Standards Test 345
	70	1" perlite-gypsum plaster,[2] no reinforcement. x = 3/4"	1 1/2	Nat'l Bureau of Standards BMS 141—Test 295
	71	1/2" perlite-gypsum plaster,[2] no reinforcement. x = 3/4"	1	Nat'l Bureau of Standards BMS 141—Tests 317, 319
	72	3/4" mineral fiber acoustic tile suspended from runners and T-shaped clipped splines.[38]	4*	Underwriters' Lab., Inc. Ret. 4177-2 (Design 21-4 hr.)

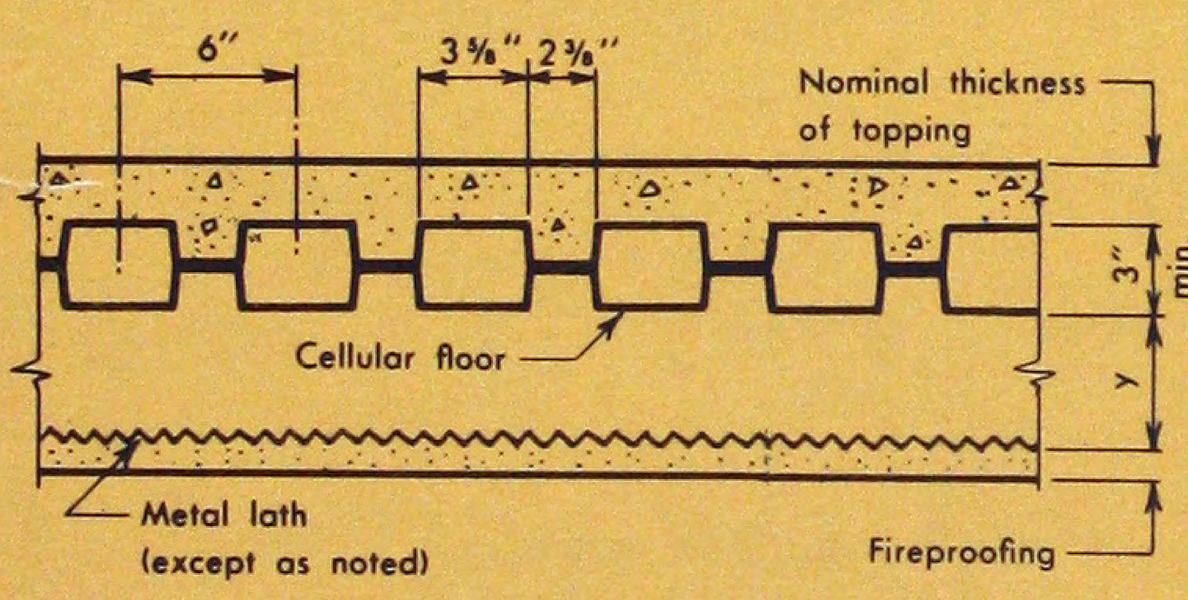
Beams, Girders and Trusses: Fire-protected by a Membrane Ceiling (cont.)





Drawing	No.	Description	Rating (Hours)	Authority [1]
	73	4" of mineral wool insulating batts (2 layers, 2" thick each), plus $\frac{3}{4}$" perforated glass fiber acoustic tile clipped to furring channels.	2	Underwriters' Lab., Inc. Ret. 3583-1 (Design 1-2 hr.)
	74	$\frac{1}{2}$" gypsum wallboard, nailed 6" o.c. into nailing channels, over $\frac{5}{8}$" gypsum coreboard. Joints of wallboard staggered from coreboard joints.	$1\frac{1}{2}$	Underwriters' Lab., Inc. Ret. 1319-26 (Design 2-$1\frac{1}{2}$ hr.)
	75	One layer $\frac{5}{8}$" gypsum wallboard or coreboard nailed into nailing channels, or screwed into furring channels.	1	Underwriters' Lab., Inc. Ret. 2717-16 (Design 2-1 hr.) Ret. 1319-14 (Design 5-1 hr.) Ret. 3501-18 (Design 8-1 hr.)

Floor and Roof Systems: Light Gauge Steel Systems – Membrane Fireproofed

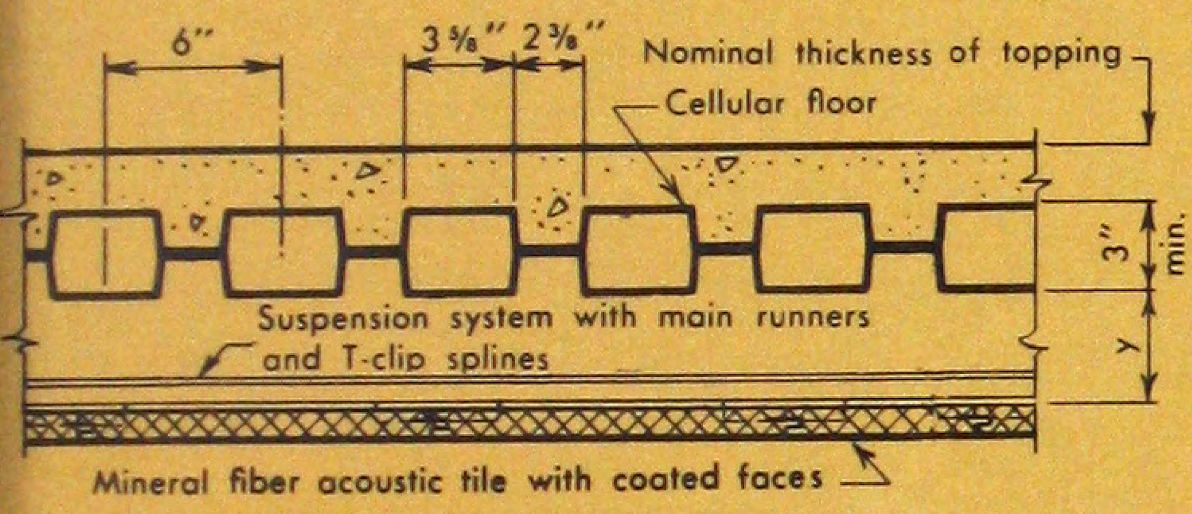
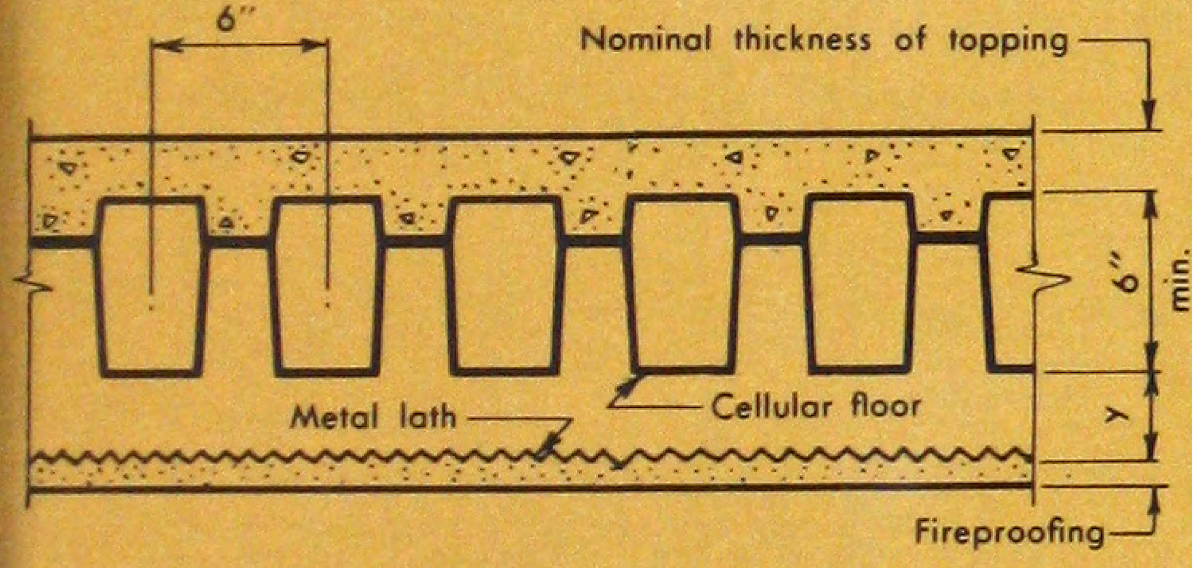
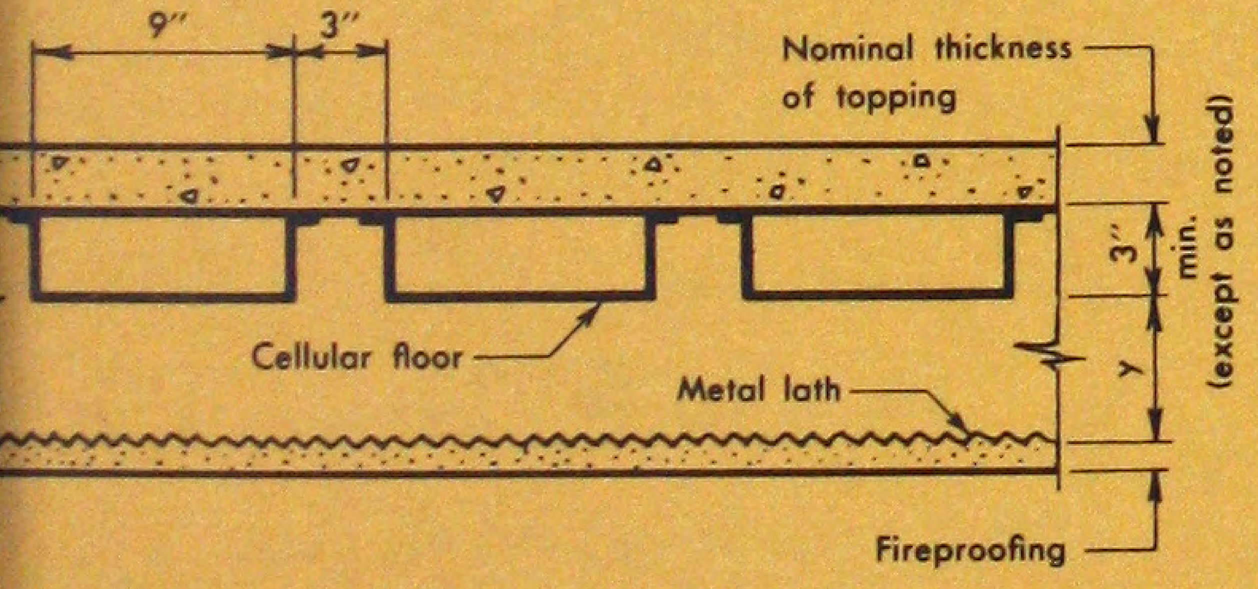


y = minimum clearance from underside of steel floor to back of lath.

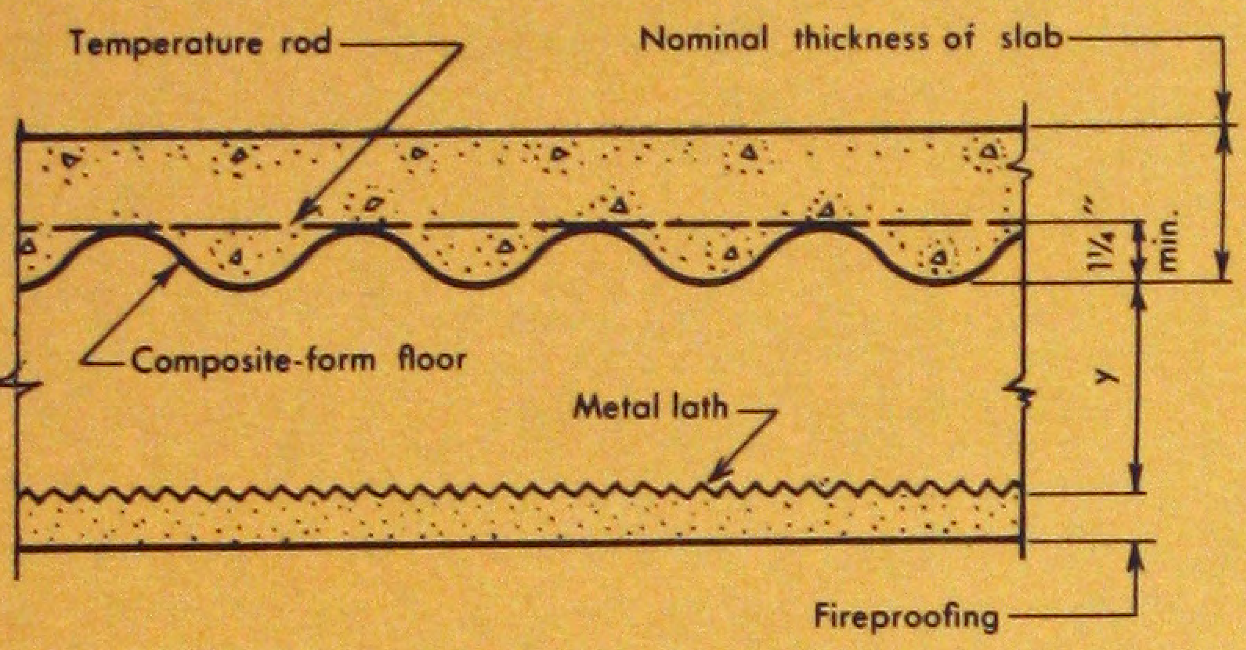
Drawing	No.	Description	Rating (Hours)	Authority
	76	Topping: 2" sand-gravel concrete. Fireproofing: 1" vermiculite-gypsum plaster [26] on metal lath. y = 2"	4	Nat'l Bureau of Standards BMS 92—Table 45
	77	Topping: 2" perlite-concrete. Fireproofing: 1" perlite-gypsum plaster on metal lath. y = 3"	4	Underwriters' Lab., Inc. Ret. 2993 (Design 3-4 hr.)
	78	Topping: 2" sand-gravel concrete. Fireproofing: 1" neat fibered gypsum plaster [2] on metal lath.[8] y = 9"	4	Nat'l Bureau of Standards BMS 92—Table 45
	79	Topping: $2\frac{1}{2}$" sand-gravel concrete. Fireproofing: $\frac{5}{8}$" vermiculite-gypsum plaster [2] base plus $\frac{1}{2}$" finish vermiculite acoustic plaster.[15] (Total thickness $1\frac{1}{8}$" over face of metal lath). y = $7\frac{1}{4}$"	4	Underwriters' Lab., Inc. Ret. 2773-5 (Design 4-4 hr.)
	80	Topping: $2\frac{1}{2}$" sand-gravel concrete. Fireproofing: $\frac{3}{4}$" perlite-gypsum plaster [2] base plus $\frac{1}{2}$" acoustic plaster.[15] (Total thickness $1\frac{1}{4}$" over face of metal lath). y = $7\frac{1}{4}$"	4*	Nat'l Bureau of Standards Test 338
	81	Topping: $3\frac{1}{4}$" sand-gravel concrete. Fireproofing: 1" perlite-gypsum plaster [2] on metal lath [24] tied directly to underside of floor. y = 0"	4*	Underwriters' Lab., Inc. Ret. 3789-1 (Design 15-5 hr.)
	82	Topping: 2" sand-gravel concrete. Fireproofing: $\frac{7}{8}$" vermiculite-gypsum plaster [2] on metal lath.[8] y = $15\frac{3}{8}$" Note: Ceilings pierced with duct openings (85 sq. inches in each 100 sq. feet of ceiling area) and electrical outlets (one in each 90 sq. feet of ceiling area). Duct openings protected with fusible link dampers.	3	Underwriters' Lab., Inc. Ret. 2689 (Design 1-3 hr.)

Note: Superior numbers refer to notes on page 40.

Asterisks (*) identify tests conducted 5 hours or more without reaching critical limits.

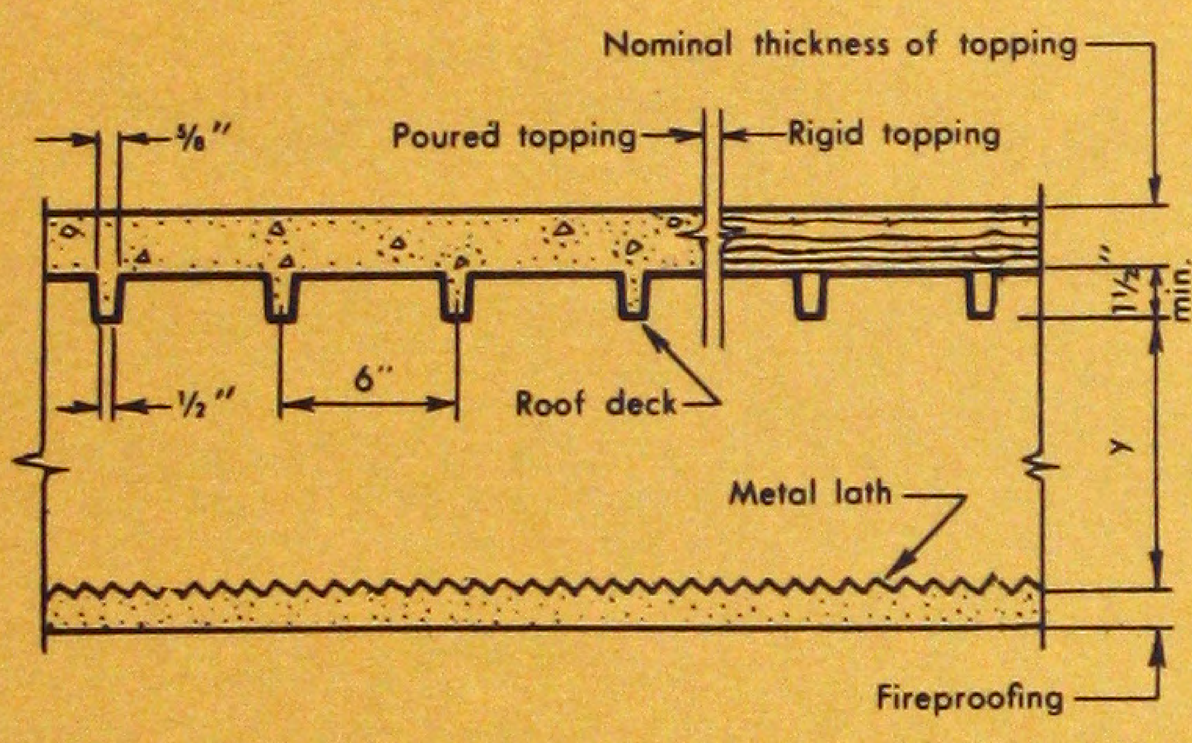
Drawing	No.	Description	Rating (Hours)	Authority [1]
(See drawing, bottom of page 32)	83	Topping: 2" sand-gravel concrete. Fireproofing: ¾" perlite-gypsum plaster [2] on metal lath.[8] y = 15½" Note: Ceilings pierced same as No. 82 above, except duct openings 113 sq. inches in each 100 sq. feet of ceiling area.	3	Underwriters' Lab., Inc. Ret. 3574-6 (Design 11-3 hr.)
	84	Topping: 2" sand-gravel concrete. Fireproofing: 1" neat fibered gypsum plaster on metal lath. y = 2"	3	Nat'l Bureau of Standards BMS 92—Table 45
	85	Topping: 2½" sand-gravel concrete. Fireproofing: ½" perlite-gypsum plaster [2] on ⅜" perforated gypsum lath. y = 7¼"	3	Nat'l Bureau of Standards Test 337
	86	Topping: 2" sand-gravel concrete. Fireproofing: 1" sprayed mineral fibers [15] on metal lath [24] coated with special adhesive. y = 4¼"	3	Underwriters' Lab., Inc. Ret. 2923-1 (Design 2-3 hr.)
	87	Topping: 2½" sand-gravel concrete. Fireproofing: ¾" mineral fiber acoustic tiles, tongued and grooved, on T-spline suspension system. y = 10⅞"	4	Underwriters' Lab., Inc. Ret. 4177-2 (Design 21-4 hr.)
 y = minimum clearance from underside of steel floor to back of lath.	88	Topping: 2" cinder-concrete. Fireproofing: ⅞" vermiculite-gypsum plaster [2] on metal lath.[8] y = 2½"	4	Underwriters' Lab., Inc. Ret. 2689 (Design 1-4 hr.)
 y = minimum clearance from underside of steel floor to back of lath.	89	Topping: 2" sand-gravel concrete. Fireproofing: ⅞" perlite-gypsum plaster [2] on metal lath.[8] y = 15½" Note: Ceilings pierced with duct openings (70 sq. inches in each 100 sq. feet of ceiling area) and electrical outlets (one in each 90 sq. feet of ceiling area). Duct openings protected by fusible link dampers.	4	Underwriters' Lab., Inc. Ret. 3355 (Design 5-4 hr.)
	90	Same as No. 89 above, except: y = 14¾"	3	Underwriters' Lab., Inc. Ret. 3724-1 (Design 8-3 hr.)
	91	Topping: 2" sand-gravel concrete. Fireproofing: 1⅛" sprayed mineral fibers [15] applied to metal lath [24] coated with special adhesive. y = 4½" Note: Minimum depth of cellular floor to be 4½".	3	Underwriters' Lab., Inc. Ret. 3372-1 (Design 4-3 hr.)

Floor and Roof Systems: Light Gauge Steel Systems – Membrane Fireproofed (cont.)



y = minimum clearance from underside of steel floor to back of lath.

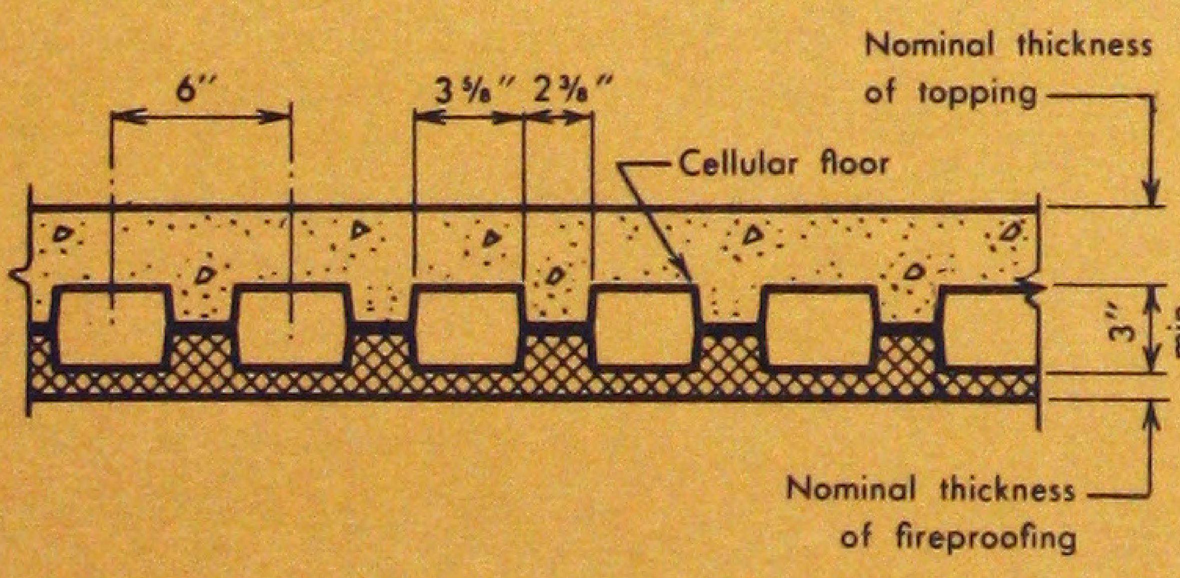
No.	Description	Rating (Hours)	Authority[1]
92	Slab: 4½" sand-gravel concrete. Fireproofing: 1" vermiculite-gypsum plaster[2] on metal lath.[8] y = 14½"	4	Underwriters' Lab., Inc. Ret. 3413-1 (Design 7-4 hr.)



y = minimum clearance from underside of steel floor to back of lath.

No.	Description	Rating (Hours)	Authority[1]
93	Topping: 2" sand-gravel concrete. Fireproofing: 1 5/16" perlite-gypsum plaster[2] on metal lath.[8] y = 15½" Note: Ceilings pierced with duct openings (113 sq. inches in each 100 sq. feet of ceiling area) and electrical outlets (one in each 90 sq. feet of ceiling area). Duct openings protected with fusible link dampers.	4	Underwriters' Lab., Inc. Ret. 3574 (Design 12-4 hr.)
94	Topping: 2" precast vermiculite concrete.[32] Fireproofing: 1" vermiculite-gypsum plaster[2] on metal lath.[8] y = 10¾"	4	Nat'l Bureau of Standards TR 10235-2 Test No. 60
95	Topping: 1" thick insulation board[37] of shredded wood bonded with portland cement, over layer of 15 lbs. asphalt saturated asbestos-felt cemented to deck as a seal sheet. Fireproofing: 1" vermiculite-gypsum plaster[2] on metal lath.[8] y = 10¾"	3	Nat'l Bureau of Standards TR 10235-2 Test No. 60
96	Topping: 1" thick insulation board[37] of felted glass fiber, covered on underside with impregnated paper vapor seal. Fireproofing: 1" vermiculite-gypsum plaster[2] on metal lath.[8] y = 10¾"	2	Nat'l Bureau of Standards TR 10235-2 Test No. 60

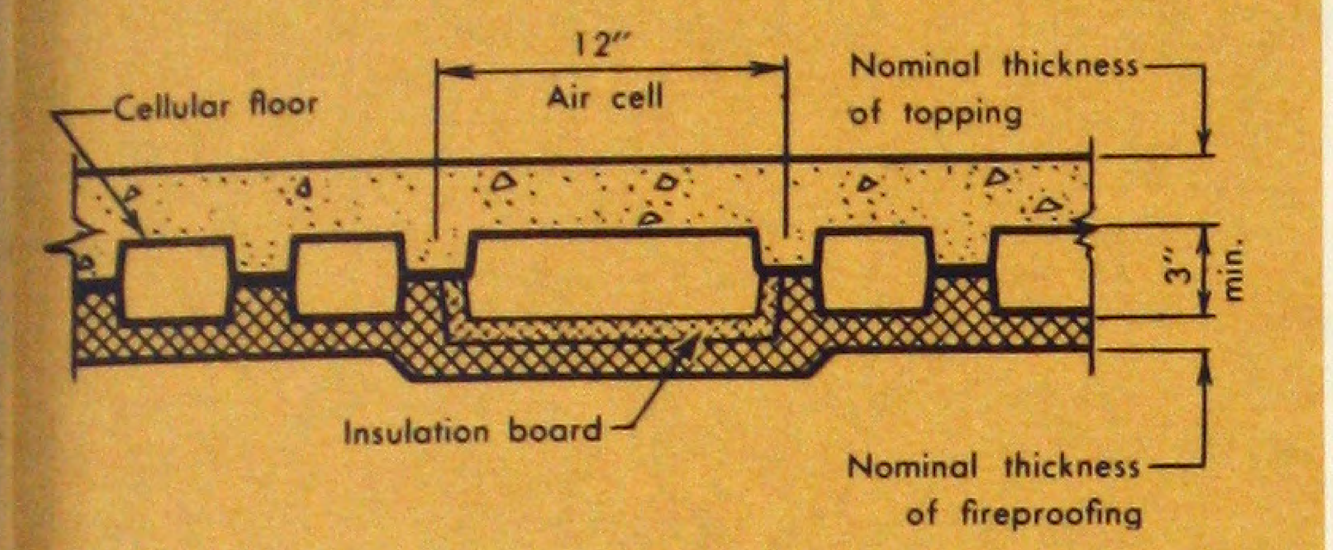
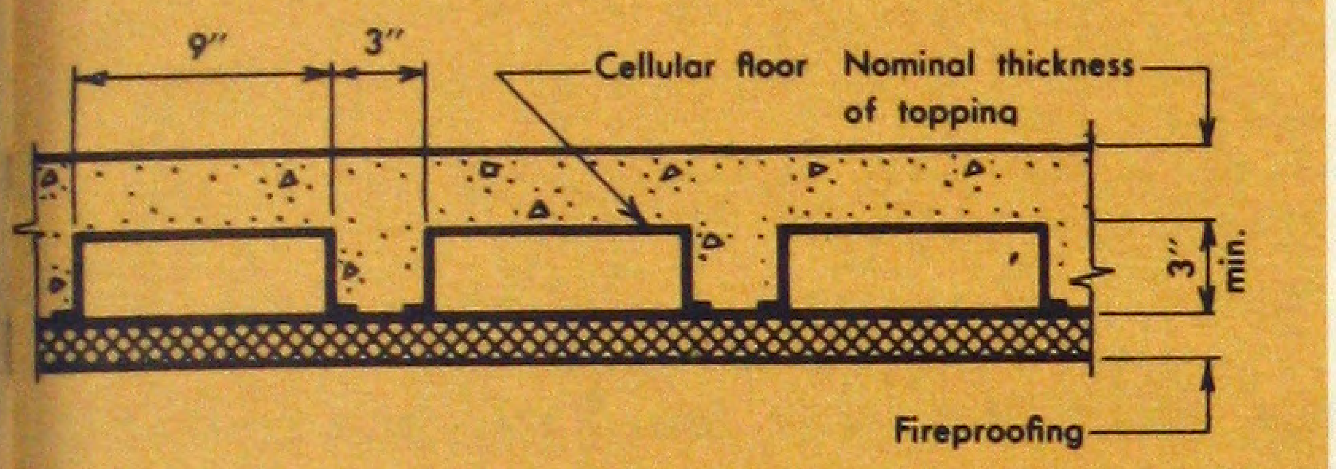
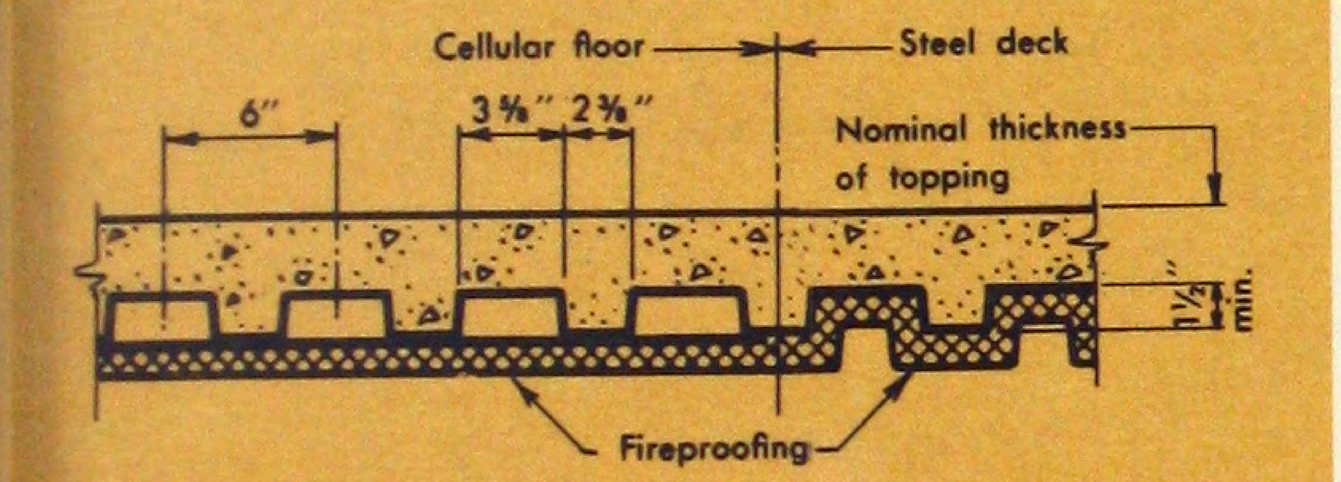
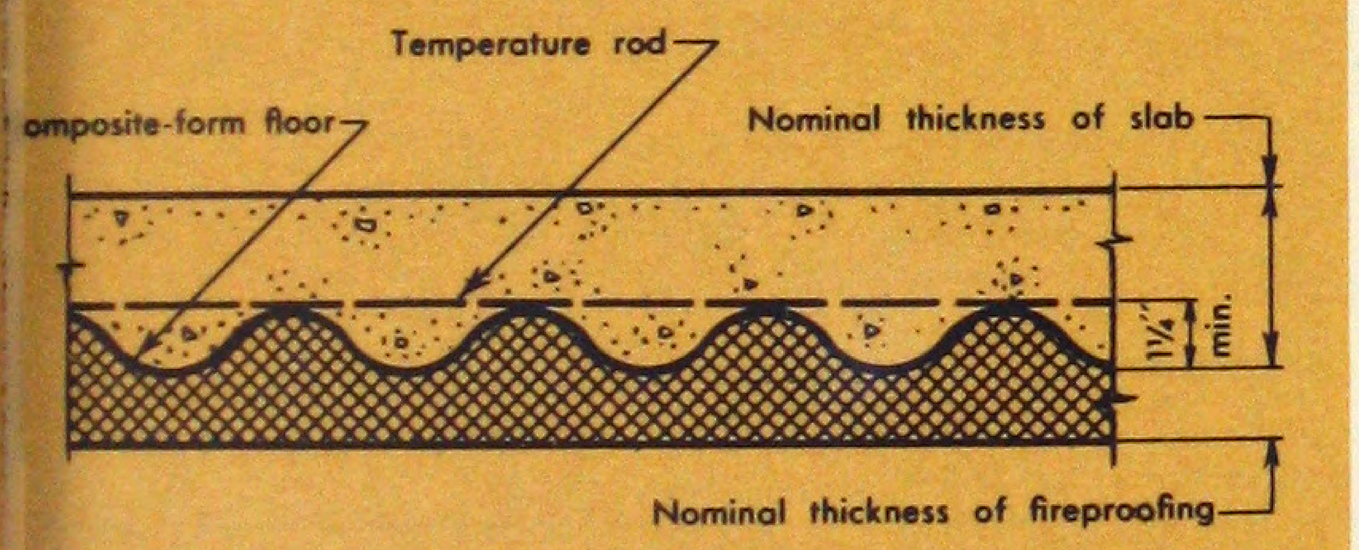
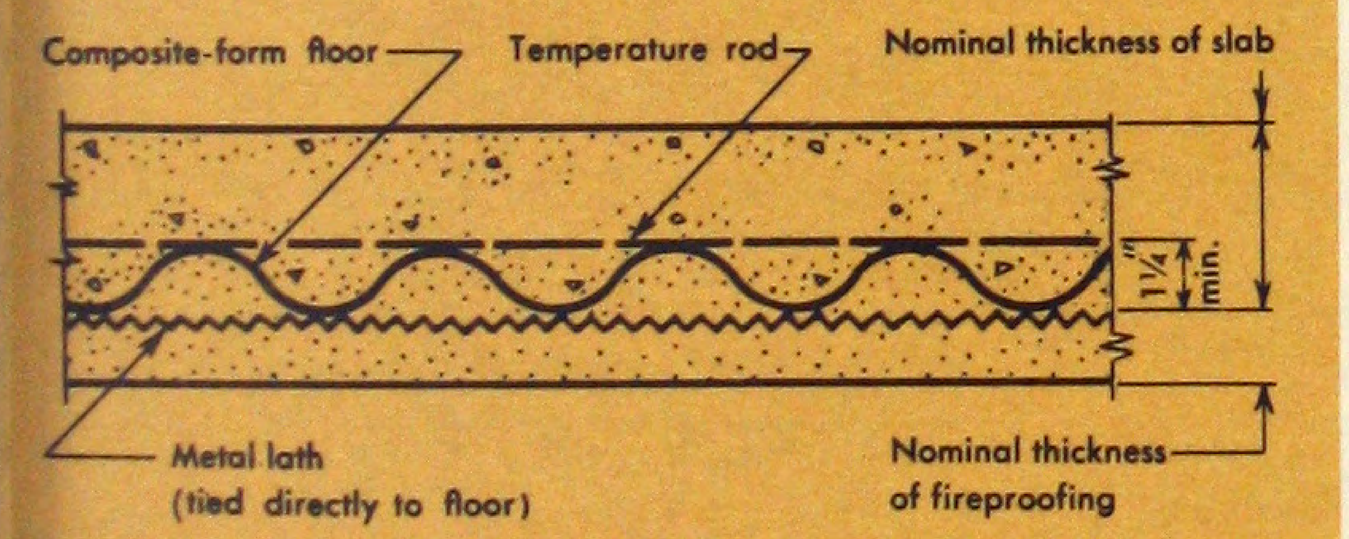
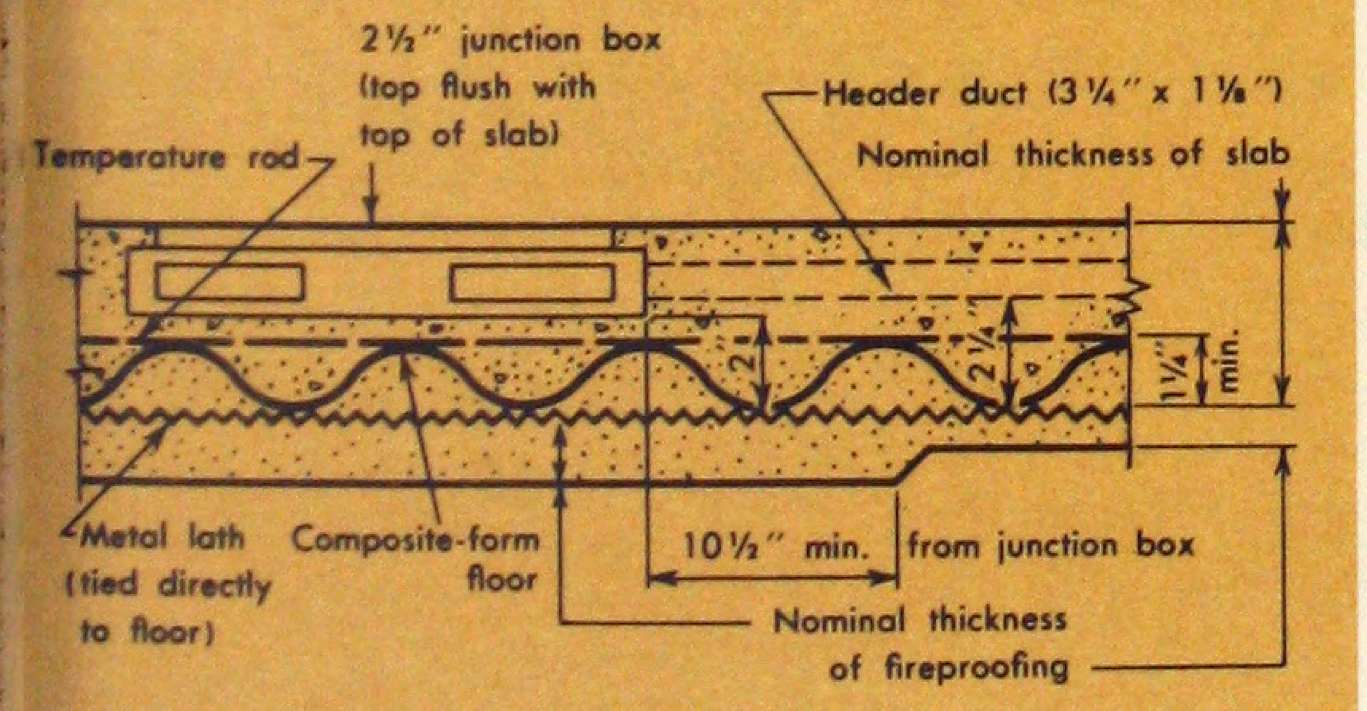
Floor and Roof Systems: Light Gauge Steel Systems – Contact Fireproofed



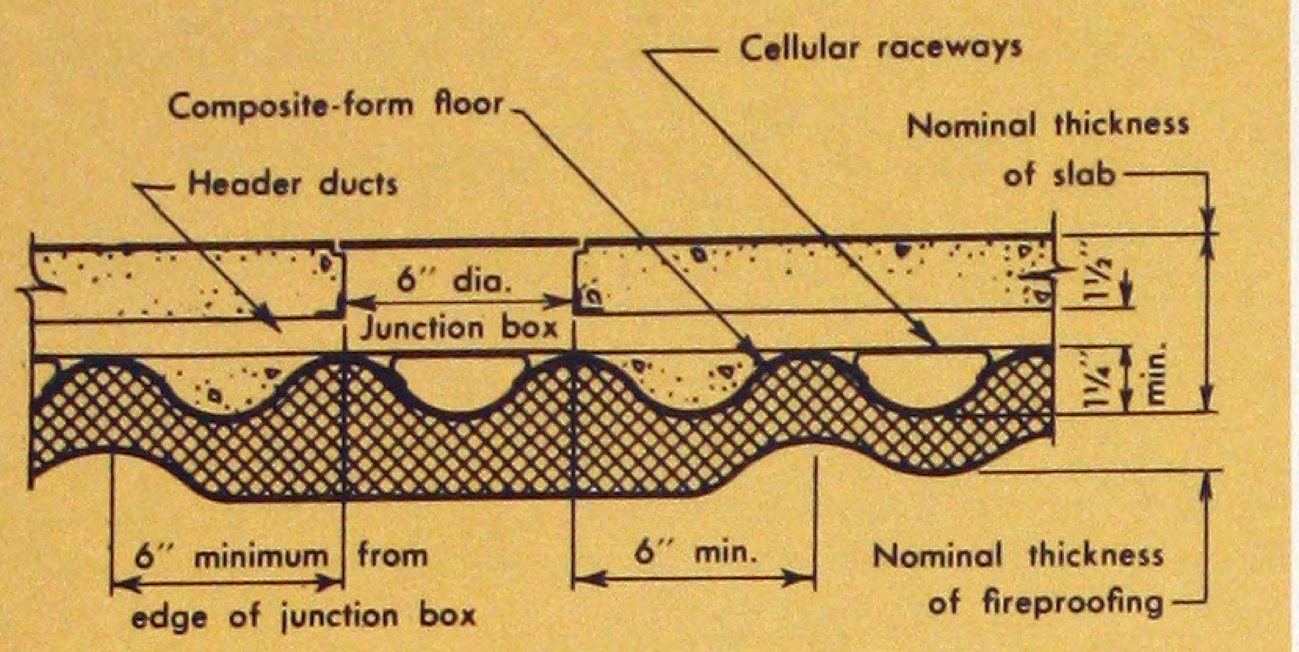
No.	Description	Rating (Hours)	Authority[1]
97	Topping: 2½" sand-gravel concrete. Fireproofing: ½" sprayed mineral fibers.[15] No adhesive.	4	Underwriters' Lab., Inc. Ret. 3705-3 (Design 20-4 hr.)
98	Topping: 2½" sand-gravel concrete. Fireproofing: 1 1/16" vermiculite acoustic plaster.[15]	4	Underwriters' Lab., Inc. Ret. 2689-5 (Design 19-4 hr.)
99	Topping: 2½" sand-gravel concrete. Fireproofing: ½" vermiculite acoustic plaster.[15]	2½[23]	Underwriters' Lab., Inc. Ret. 2689-3 (Design 2-2 hr.)

Note: Superior numbers refer to notes on page 40.

Asterisks (*) identify tests conducted 5 hours or more without reaching critical limits.

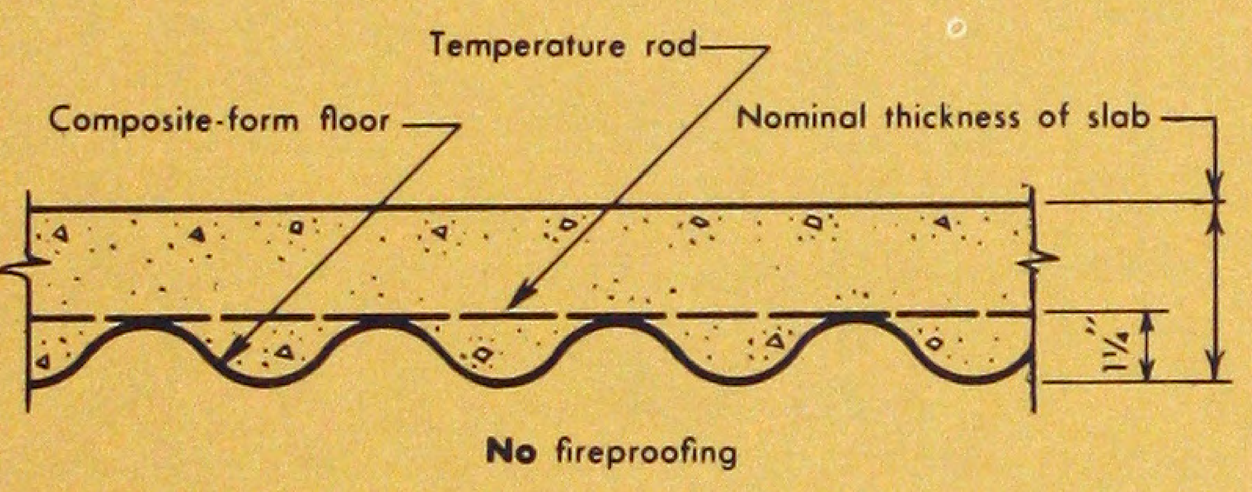
Drawing	No.	Description	Rating (Hours)	Authority [1]
	100	Same as No. 98 above, except: 24" wide air cell added to construction, with $\frac{3}{4}$" thick aluminum foil faced fiber glass insulation board [31] plus 1$\frac{1}{8}$" vermiculite acoustic plaster [15] under air cell.	4	Underwriters' Lab., Inc. Ret. 2689-5 (Design 19-4 hr.)
	101	Topping: 2$\frac{1}{2}$" sand-gravel concrete. Fireproofing: 1$\frac{1}{2}$" sprayed mineral fibers.[15] Special adhesive pre-applied to underside of steel floor.	4*	Underwriters' Lab., Inc. Ret. 3431-2 (Design 17-5 hr.)
	102	Topping: 2$\frac{1}{2}$" sand-gravel concrete. Fireproofing: $\frac{3}{4}$" sprayed mineral fibers [15] **or** 1$\frac{7}{16}$" vermiculite acoustic plaster.[15] Sprayed fibers require special adhesive pre-applied to underside of steel floor.	3	Underwriters' Lab., Inc. Ret. 2689-4 (Design 12-3 hr.) Ret. 3749-3 (Design 14-3, 15-3 hr.)
	103	Topping: 2$\frac{1}{2}$" sand-gravel concrete. Fireproofing: $\frac{1}{2}$" sprayed mineral fibers.[15] Special adhesive pre-applied to underside of steel floor. (Tested on cellular units only).	2	Underwriters' Lab. of Canada Ret. 193-3
	104	Slab: 4$\frac{1}{2}$" sand-limestone concrete. Fireproofing: $\frac{1}{2}$" vermiculite acoustic plaster.[15]	4	Underwriters' Lab., Inc. Ret. 3413-7 (Design 10-4 hr.)
	105	Slab: 4$\frac{1}{2}$" sand-limestone concrete. Fireproofing: $\frac{7}{8}$" sprayed mineral fibers.[15] Special adhesive pre-applied to underside of steel floor.	4	Underwriters' Lab., Inc. Ret. 3372-2 (Design 9-4 hr.)
	106	Slab: 4$\frac{1}{2}$" expanded slag concrete. Fireproofing: $\frac{3}{8}$" perlite-gypsum plaster [2] on metal lath [8] attached directly to floor. Sufficient plaster pushed through lath to fill corrugations in the floor units.	4	Underwriters' Lab., Inc. Ret. 3413-4 (Design 8-4 hr.)
	107	Same as No. 106 above, except: Electrical raceways and junction boxes built into floor slab. Plaster thickness below junction boxes to be 1". Not more than one junction box per 90 sq. feet of floor area.	3	Underwriters' Lab., Inc. Ret. 3413-4 (Design 5-3 hr.)

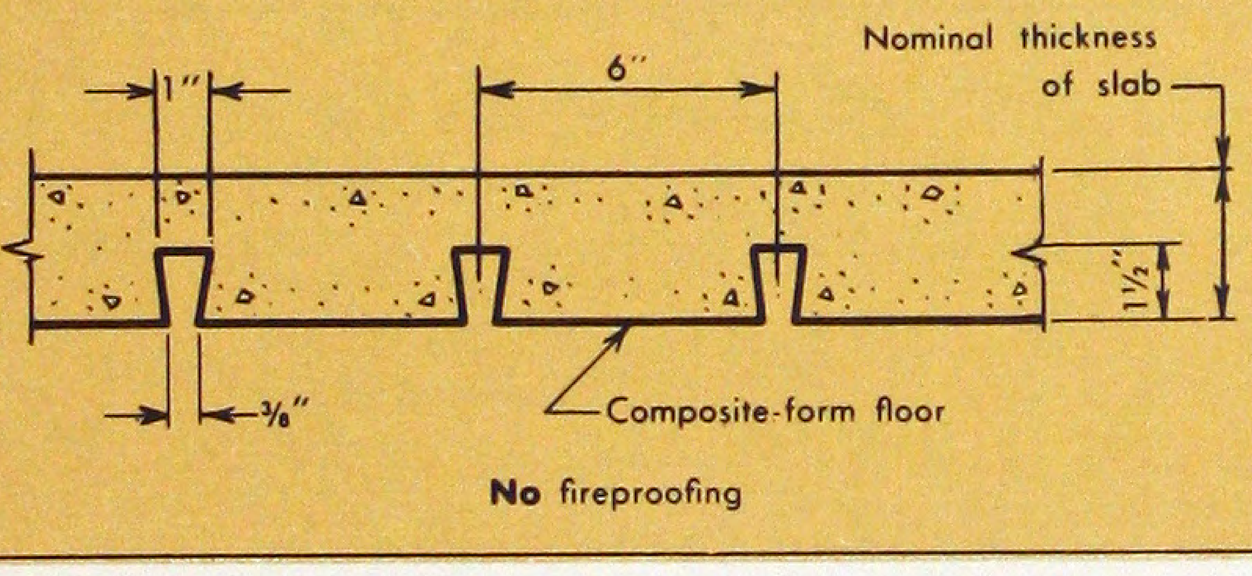
Floor and Roof Systems: Light Gauge Steel Systems – Contact Fireproofed (cont.)



Drawing	No.	Description	Rating (Hours)	Authority[1]
See drawing above	108	Slab: 4½" expanded shale concrete with header ducts and junction boxes built in. Header ducts rest on steel floor. (Duct size 6¼" wide by 1½" deep, spaced 9½" apart). Fireproofing: ¾" perlite acoustic plaster[15] following contour of form, except 2" thick under junction boxes.	4	Underwriters' Lab., Inc. Ret. 3983-1
	109	Same as No. 108 above, except: Fireproofing: **None** except 1" perlite acoustic plaster[15] under cellular raceways, ⅞" under header ducts, 2" under junction boxes.	2½[23]	Underwriters' Lab., Inc. Ret. 3413-11 (Design 7-2 hr.)

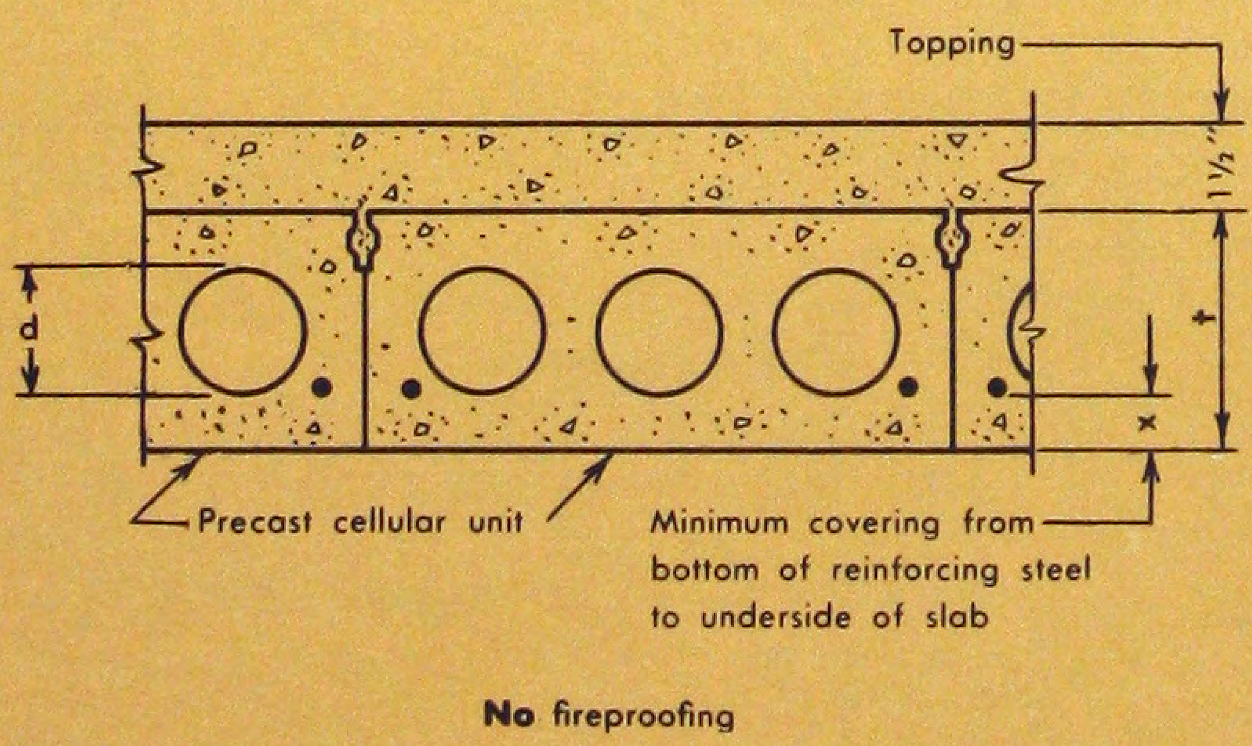
Floor and Roof Systems: Light Gauge Steel Systems – Not Fireproofed





Drawing	No.	Description	Rating (Hours)	Authority[1]
	110	Slab: 4½" expanded shale concrete.	3	Underwriters' Lab., Inc. Ret. 3413-9 (Design 7-3 hr.)
	111	Slab: 5¼" sand-limestone concrete.	2½[23]	Underwriters' Lab., Inc. Ret. 3413-10 (Design 3-2 hr.)
	112	Slab: 3½" perlite-concrete.[32] (On corrugated form floor without temperature rods welded to form).	1½[33]	Underwriters' Lab., Inc. Ret. 3413-8 (Design 6-1 hr.)
	113	Slab: 4½" sand-limestone concrete.	1	Underwriters' Lab., Inc. Ret. 3413-5 (Design 3-1 hr.)
	114	Slab: 3" vermiculite-concrete.[34]	1½	Underwriters' Lab., Inc. Ret. 2773-6 (Design 1-1½ hr.)

Floor and Roof Systems: Precast Concrete Cellular Systems – Not Fireproofed

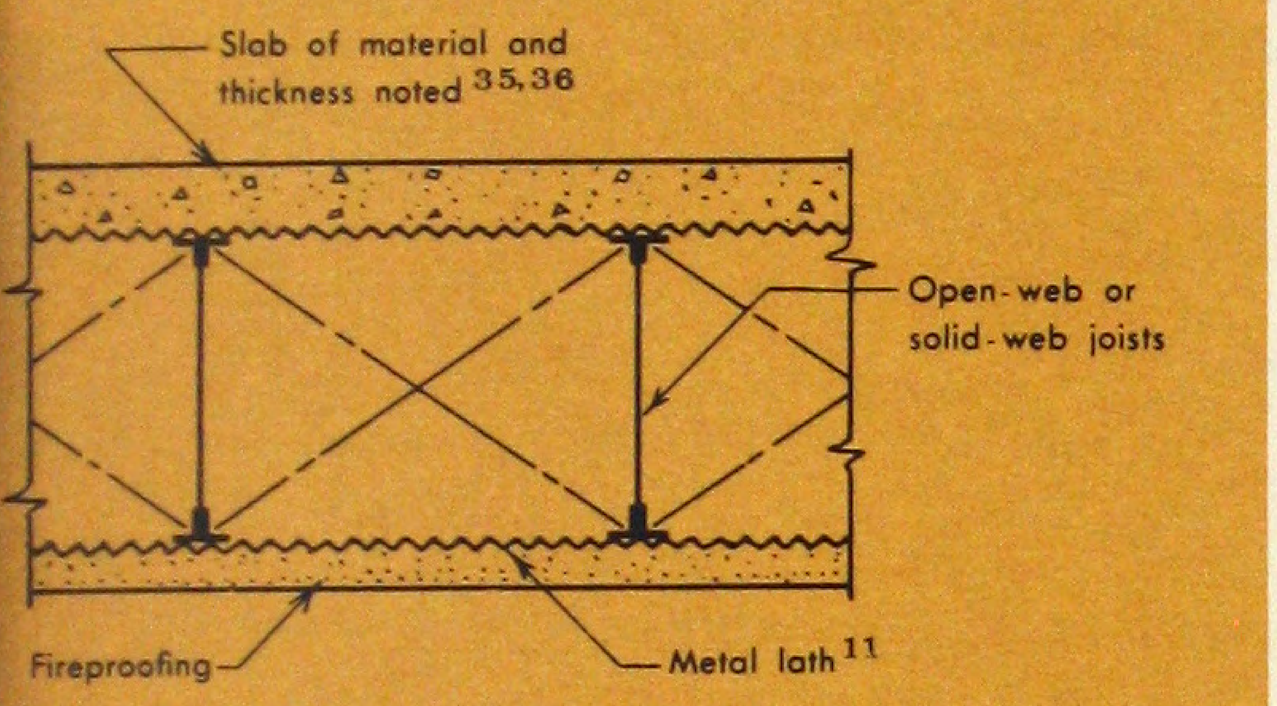


Drawing	No.	Description	Rating (Hours)	Authority[1]
	115	Topping: 1⅞" expanded slag concrete. Precast unit: Expanded slag concrete. Unit thickness (t) = 4" Covering of reinforcing steel (x) = 31/32" Depth of cellular core (d) = 2"	4	Nat'l Bureau of Standards TR 10218-28: FP 3490 Test 403
	116	Topping: 1½" sand-gravel concrete. Precast unit: Limestone concrete. Unit thickness (t) = 6" Covering of reinforcing steel (x) = 15/16" Depth of cellular core (d) = 4"	3	Nat'l Bureau of Standards TG 10210-2020: FP 3446 Test 398
	117	Topping: 1½" sand-gravel concrete. Precast unit: Limestone concrete. Unit thickness (t) = 8" Covering of reinforcing steel (x) = 15/16" Depth of cellular core (d) = 6⅛"	3	Underwriters' Lab., Inc. Ret. 3774-1

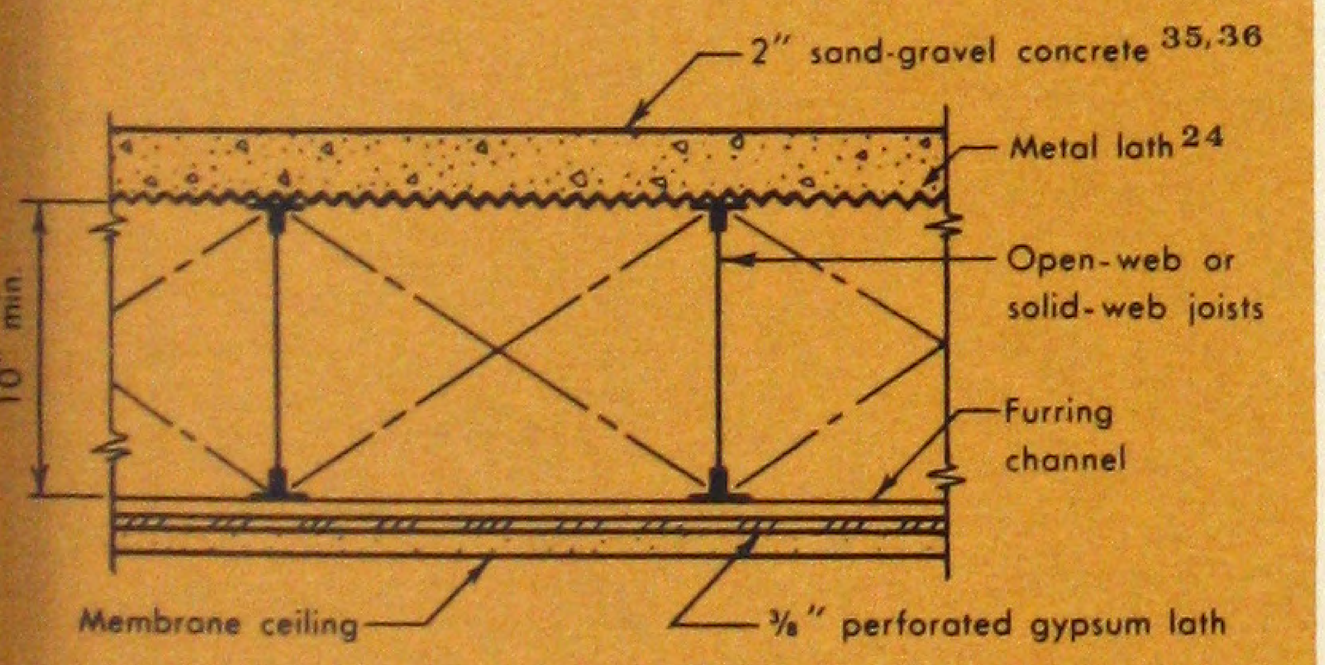
Note: Superior numbers refer to notes on page 40.

Floor and Roof Systems:

Joist and Slab Systems (Open-web or Solid-web Steel Joists)–Membrane Fireproofed



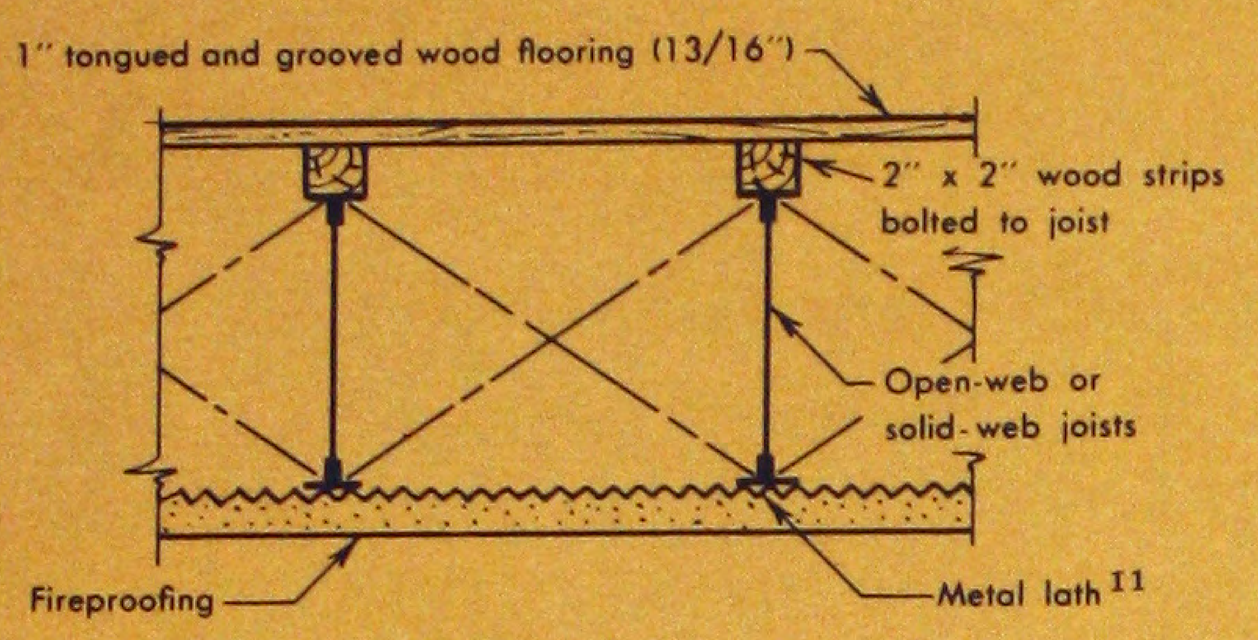
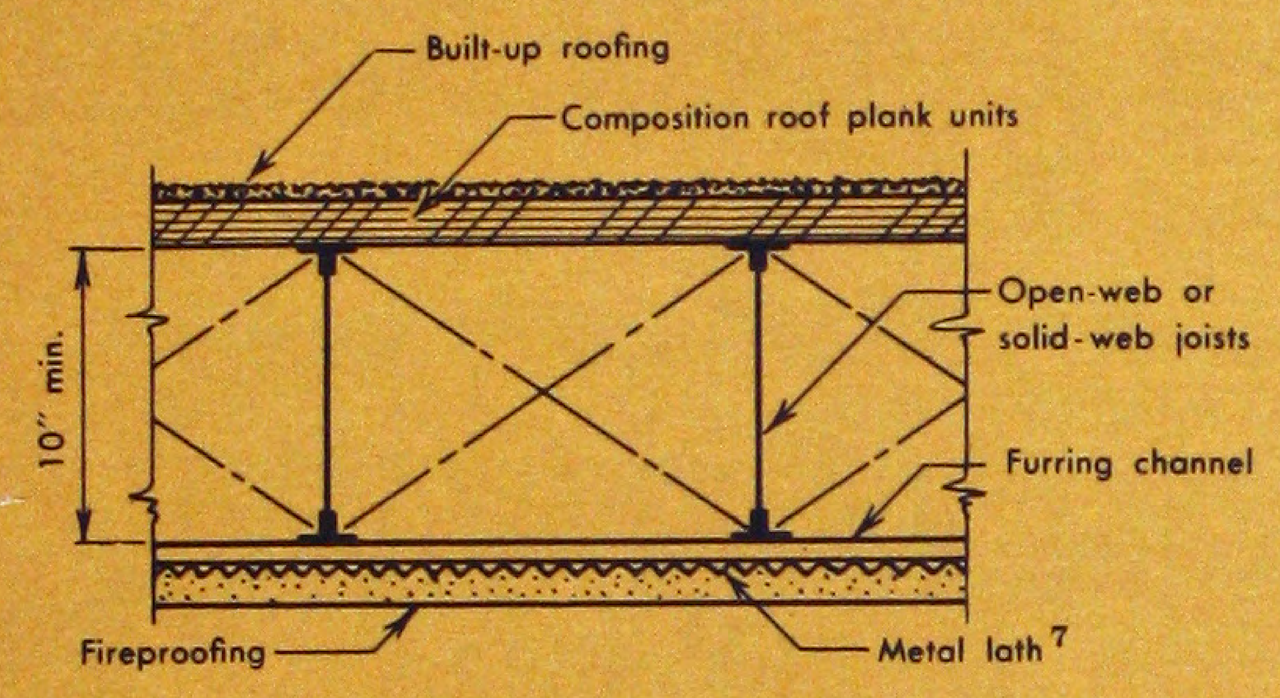
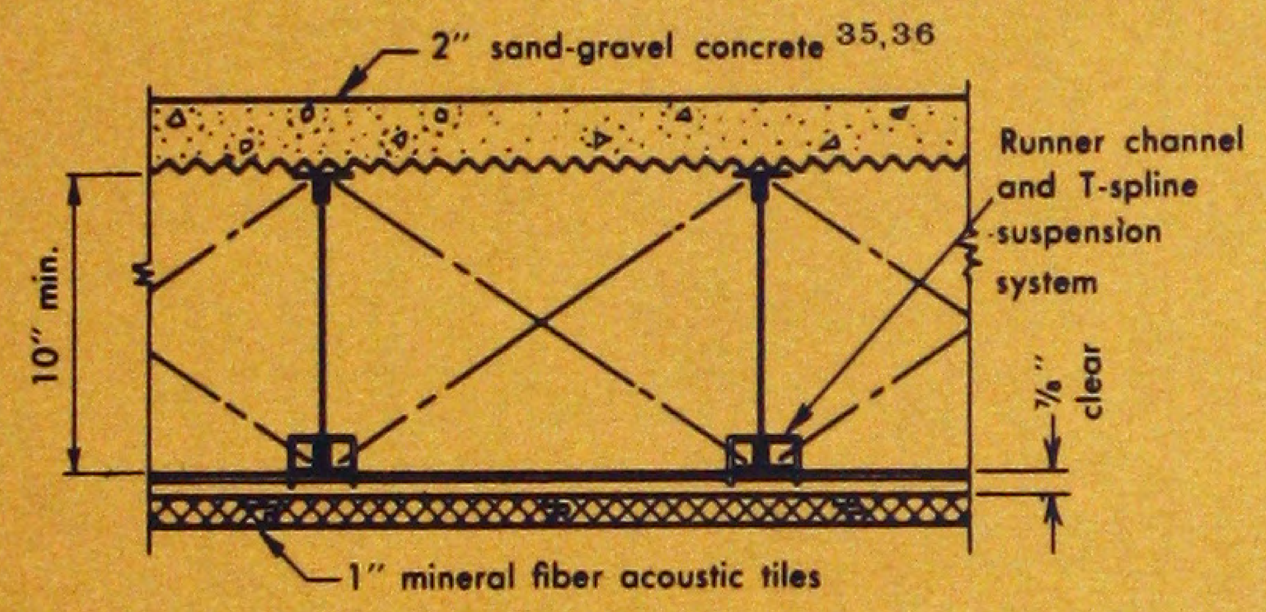
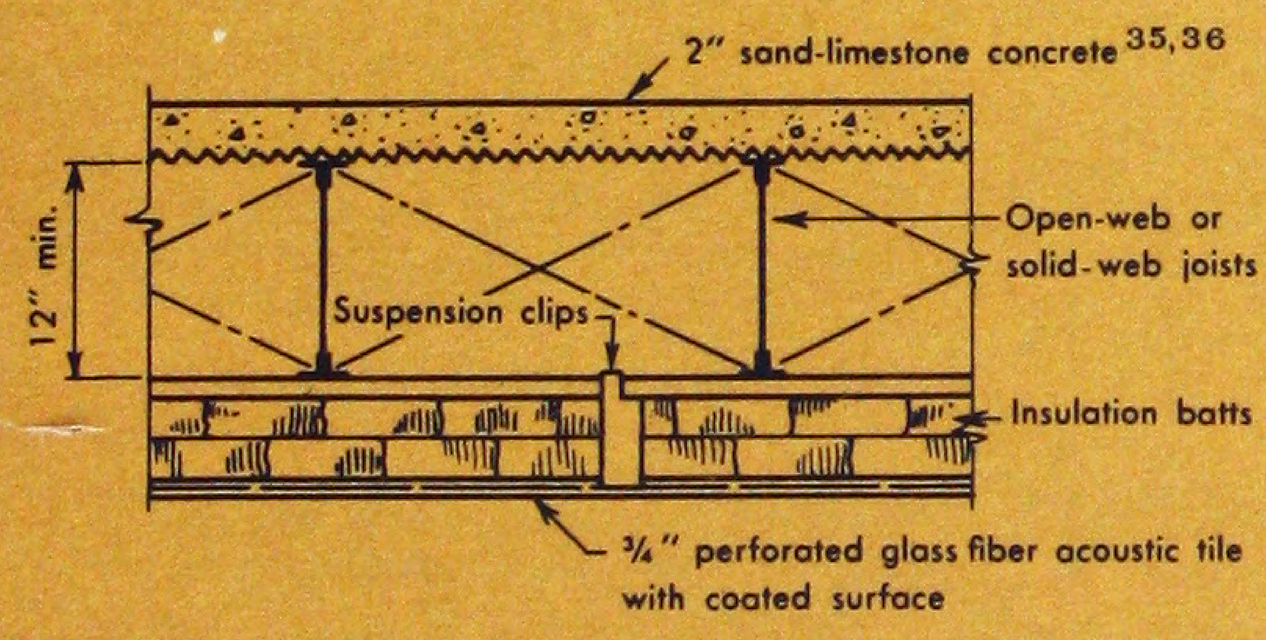
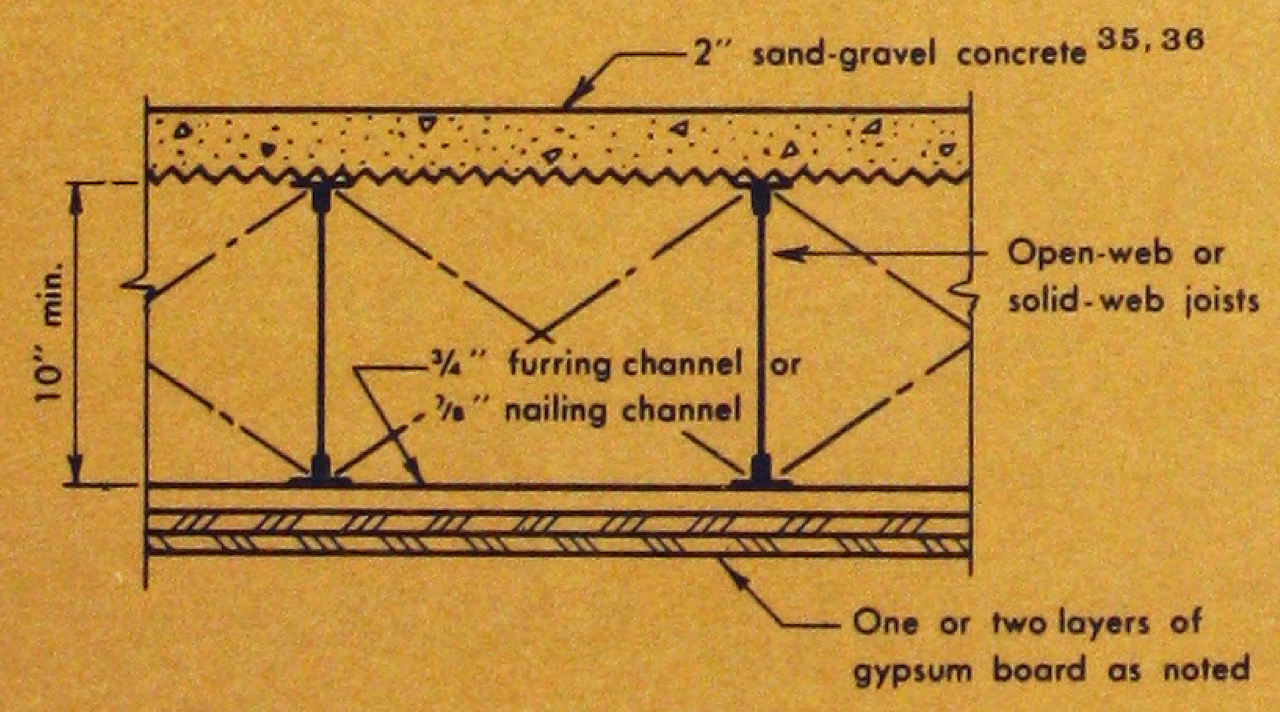
No.	Description	Rating (Hours)	Authority [1]
118	Slab: 2½" sand-gravel concrete **(or** 2" gypsum tile covered with ½" mortar). Ceiling: 1" vermiculite-gypsum plaster.[26]	4	Nat'l Bureau of Standards BMS 92—Table 43
119	Slab: 2½" sand-gravel concrete **(or** 2" gypsum tile covered with ½" mortar). Ceiling: ¾" vermiculite-gypsum plaster [26] **or** 1" neat wood-fibered gypsum plaster.	3	
120	Slab: 2½" perlite-concrete.[32] Ceiling: ¾" perlite-gypsum plaster.[2]	3	Underwriters' Lab., Inc. Ret. 3454-2 (Design 6-3 hr.)
121	Slab: 2" sand-gravel concrete **(or** 2" gypsum tile covered with ¼" mortar). Ceiling: ¾" vermiculite-gypsum plaster [26] **or** 1" neat wood-fibered gypsum plaster.	2½	Nat'l Bureau of Standards BMS 92—Table 43 TRBM 44—Table 18
122	Slab: 2½" sand-gravel concrete. Ceiling: 1" sprayed asbestos fibers.[15]	2½	
123	Slab: 2¼" sand-gravel concrete **(or** 2" gypsum tile covered with ¼" mortar). Ceiling: ¾" sand-gypsum plaster.[26]	2	
124	Slab: 2½" sand-gravel concrete. Ceiling: ¾" sprayed asbestos fibers.[15]	2	
125	Slab: 2" sand-gravel concrete **(or** 2" gypsum tile, no top mortar). Ceiling: ¾" sand-gypsum plaster,[26] **or** ¾" sand-portland cement plaster with asbestos fibers.[30]	1½	
126	Slab: 2" sand-gravel concrete. Ceiling: ⅝" sprayed asbestos fibers.[15]	1½	



No.	Description	Rating (Hours)	Authority [1]
127	Ceiling: 1" perlite-gypsum plaster,[2] reinforced with 1" hexagonal wire mesh stretched under lath.	4	Nat'l Bureau of Standards BMS 141—Test 311
128	Ceiling: ½" perlite-gypsum plaster,[2] reinforced with 1" hexagonal wire mesh stretched under lath.	3	Nat'l Bureau of Standards BMS 141—Test 312
129	Ceiling: ⅝" perlite-gypsum plaster,[2] reinforced with No. 14 ga. galvanized wires secured below lath on the diagonal.	3	Nat'l Bureau of Standards BMS 141—Test 313
130	Ceiling: Same as No. 129 above, except: ½" thickness of plaster.	2½	Nat'l Bureau of Standards BMS 141—Test 318
131	Ceiling: Same as No. 129 above, except: ⅝" sand-gypsum plaster.[28]	1½	Nat'l Bureau of Standards Test 345
132	Ceiling: 1" perlite-gypsum plaster,[2] no reinforcement.	1½	Nat'l Bureau of Standards BMS 141—Test 295
133	Ceiling: ½" perlite-gypsum plaster,[2] no reinforcement.	1	Nat'l Bureau of Standards BMS 141—Tests 317, 319

Floor and Roof Systems:

Joist and Slab Systems (Open-web or Solid-web Steel Joists)–Membrane Fireproofed (cont.)

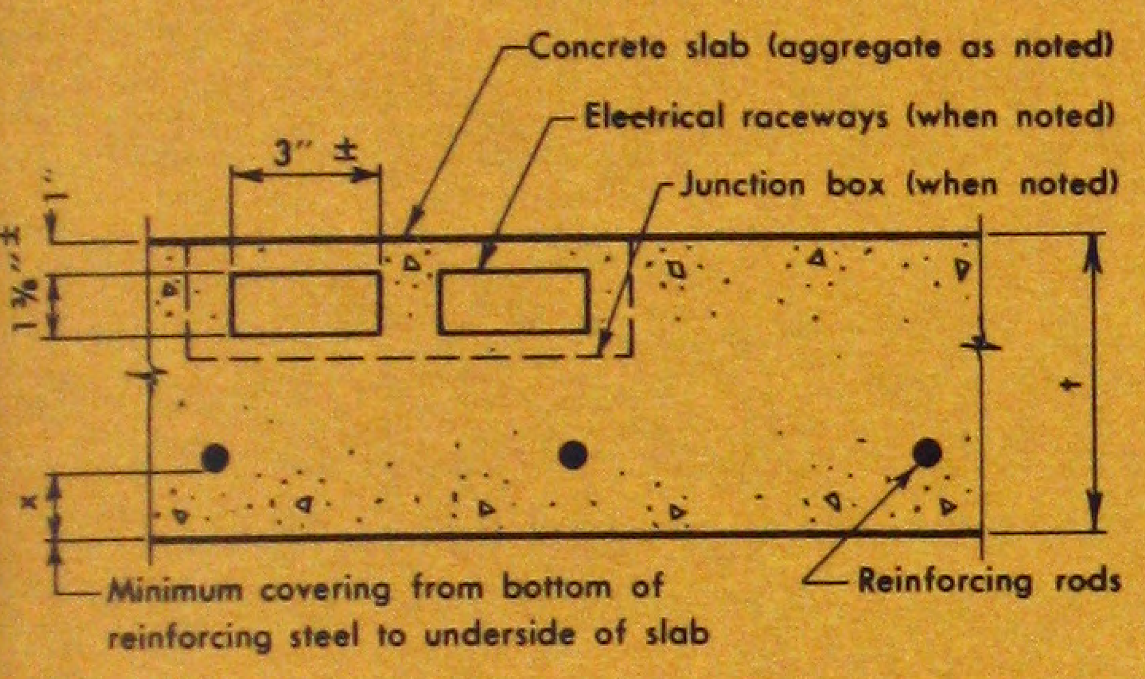
Drawing	No.	Description	Rating (Hours)	Authority [1]
	134	Ceiling: ¾" sand-gypsum plaster.[26]	1	Nat'l Bureau of Standards TRBM 44—Table 18
	135	Roof: Composition roof plank,[37] 2" thick tongued and grooved joints covered with 6" wide strips of felt and hot mopping asphalt. Screws to joists 10" o.c., holes filled with perlite-gypsum plaster.[2] Roof covering of 4-ply asphalt-saturated felt and hot mopping asphalt. Ceiling: ¾" perlite-gypsum plaster.[2]	2	Underwriters' Lab., Inc. Ret. 3472-5 (Design 4-2 hr.)
	136	Ceiling: 1" mineral fiber acoustic tiles, tongued and grooved, on T-spline suspension system.[38]	2½[23]	Underwriters' Lab., Inc. Ret. 4177-1 (Design 6-2 hr.)
	137	Ceiling: 4" of mineral wool insulating batts (2 layers of 2" thickness each) plus ¾" perforated glass fiber acoustic tile clipped to furring channels.	2	Underwriters' Lab., Inc. Ret. 3583-1 (Design 1-2 hr.)
	138	Ceiling: ½" gypsum wallboard nailed 6" o.c. into nailing channels, over ⅝" gypsum coreboard. Joints of wallboard staggered from coreboard joints.	1½	Underwriters' Lab., Inc. Ret. 1319-26 (Design 2-1½ hr.)
	139	Ceiling: One layer ⅝" gypsum wallboard or coreboard nailed into nailing channels, or screwed into furring channels.	1	Underwriters' Lab., Inc. Ret. 2717-16 (Design 2-1 hr.) Ret. 1319-14 (Design 5-1 hr.) Ret. 3501-18 (Design 8-1 hr.)

Note: Superior numbers refer to notes on page 40.

Asterisks (*) identify tests conducted 5 hours or more without reaching critical limits.

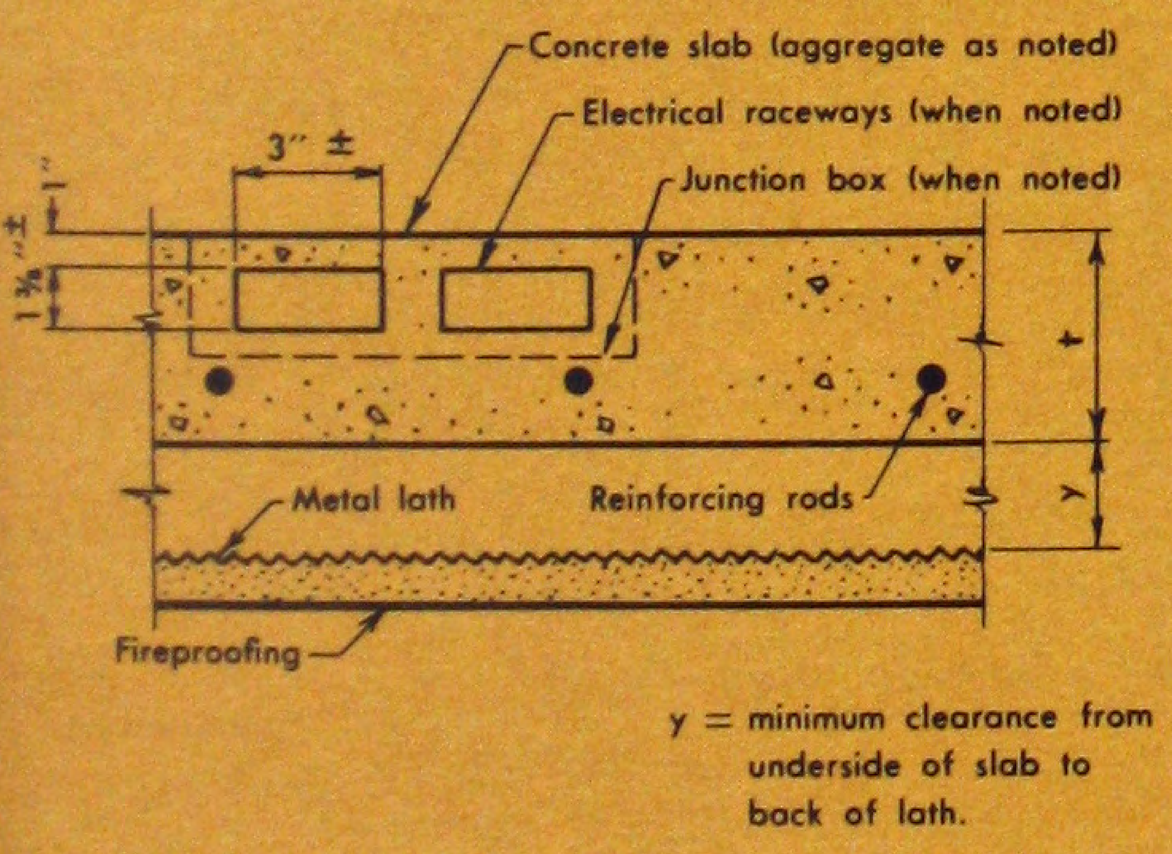
Floor and Roof Systems: Reinforced Concrete Slabs – Not Fireproofed

Drawing



No.	Description	Rating (Hours)	Authority[1]
140	Aggregate: Expanded slag. Slab thickness (t) = 4½". x = ¾"	4	Underwriters' Lab., Inc. Ret. 3390-7
141	Aggregate: Air-cooled slag. Slab thickness (t) = 6". x = 1"	4	Underwriters' Lab., Inc. Ret. 3390-12
142	Aggregate: Traprock, calcareous gravel, or crushed limestone. Slab thickness (t) = 6". x = 1"	3	Underwriters' Lab., Inc. Ret. 3390 Ret. 3390-5 Ret. 3390-10
143	Aggregate: Siliceous sand and gravel. Slab thickness (t) = 8". x = 1½"	3[39]	Nat'l Bureau of Standards Test 38A
144	Aggregate: Crushed limestone. Slab thickness (t) = 6". Tested with electrical raceways and 2½" deep junction boxes built into slab. x = 1"	3	Underwriters' Lab., Inc. Ret. 3390-17
145	Aggregate: Air-cooled slag. Slab thickness (t) = 4¾". x = ¾"	2½	Underwriters' Lab., Inc. Ret. 3390-15
146	Aggregate: Calcareous gravel or crushed limestone. Slab thickness (t) = 4¾". x = 1"	2	Underwriters' Lab., Inc. Ret. 3390-3 Ret. 3390-4
147	Aggregate: Traprock. Slab thickness (t) = 4¾". x = ¾"	2	Underwriters' Lab., Inc. Ret. 3390-9
148	Aggregate: Siliceous sand and gravel. Slab thickness (t) = 6". x = 1"	2[40]	
149	Aggregate: Siliceous sand and gravel. Slab thickness (t) = 5" or 6". x = ¾"	1½	Nat'l Bureau of Standards TRBM 44—Table 19
150	Aggregate: Siliceous sand and gravel. Slab thickness (t) = 4". x = ¾"	1	

Floor and Roof Systems: Reinforced Concrete Slabs – Membrane Fireproofed



No.	Description	Rating (Hours)	Authority
151	Aggregate: Limestone. Slab thickness (t) = 5".[41] Tested with electrical raceways and 3" deep junction boxes built into slab. Fireproofing: 1" vermiculite-gypsum plaster.[2] y = 11½"	4*	Underwriters' Lab., Inc. Ret. 3390-13
152	Aggregate: Limestone. Slab thickness (t) = 3". Fireproofing: 1" vermiculite-gypsum plaster.[2] y = 13½"	4*	Underwriters' Lab., Inc. Ret. 3390-13
153	Aggregate: Limestone. Slab thickness (t) = 4".[42] Tested with electrical raceways and 2½" deep junction boxes built into slab. Fireproofing: ¾" vermiculite-gypsum plaster.[2] y = 11½"	3	Underwriters' Lab., Inc. Ret. 3390-11
154	Aggregate: Limestone. Slab thickness (t) = 2". Fireproofing: ¾" vermiculite-gypsum plaster.[2] y = 13½"	3	Underwriters' Lab., Inc. Ret. 3390-11

Notes to Fire Resistance Ratings

1. Listed for each test conducted at Underwriters' Laboratories, Inc. is the Underwriters' Retardant Number which identifies both the test and its sponsor. Following each Retardant Number is the corresponding "Column" or "Floor, Roof and Ceiling" Design Number by which the test is identified in Underwriters' Building Materials List.
   National Bureau of Standards tests are identified by either a test number or the number of the publication in which the test result is reported.
2. Scratch Coat: 2 to 3 cu. ft. aggregate to 100 lbs. fibered gypsum.
   Brown Coat: Same.
   (Tested plaster mixes may have been 2, 2½ or 3 cu. ft. per 100 lbs. National Bureau of Standards tests indicate that this variation in ratio of vermiculite or perlite has a negligible effect on fire resistance.)
3. 3.4 lbs. per sq. yd. ⅜" diamond mesh expanded self-furring metal lath, to fur lath ¼" from steel.
4. Scratch Coat: 4 cu. ft. aggregate to 94 lbs. of portland cement and 5 oz. of air-entraining agent.
   Brown Coat: Same.
5. Paperbacked wire fabric. No. 16 ga. wire in 2" o.c. squares, with alternate squares divided by a vertical wire into 1" spaces, with 0.010 inches thick absorptive paper backing.
6. Wire fabric. No. 16 ga. wire spaced 2" o.c.
7. Scratch Coat: 3½ cu. ft. aggregate to 94 lbs. of portland cement, 8 oz. of air-entraining agent and 1 lb. of calcium aluminate cement.
   Brown Coat: Same.
8. 3.4 lbs. per sq. yd. No. 24 ga. ⅜" diamond mesh flat expanded metal lath.
9. Scratch Coat: 3 lbs. aggregate to 1 lb. fibered gypsum.
   Brown Coat: Same.
10. Scratch Coat: 2½ lbs. dry sand to 1 lb. portland cement.
    Brown Coat: Same.
11. Metal lath of appropriate weight for the spacing of supports. Expanded metal, woven wire or paperbacked.
12. Scratch Coat: 2 lbs. aggregate to 1 lb. fibered gypsum.
    Brown Coat: 3 lbs. aggregate to 1 lb. fibered gypsum.
13. Scratch Coat: 2½ lbs. aggregate to 1 lb. fibered gypsum.
    Brown Coat: Same.
14. Scratch Coat: 3½ cu. ft. aggregate to 100 lbs. unfibered gypsum.
    Brown Coat: 4 cu. ft. aggregate to 100 lbs. unfibered gypsum.
15. Sprayed mineral fiber and acoustic plaster fireproofing materials may vary with each manufacturer. Thickness listed is minimum, and tested fire rating for products of each manufacturer should be verified. The need for adhesive should be checked in each case.
16. Grade A Concrete is concrete in which at least 60% of the coarse aggregate consists of pumice, limestone, calcareous gravel, trap rock, blast furnace slag, or burned clay or shale.
17. Grade B Concrete is concrete in which at least 60% of the course aggregate consists of granite, sandstone, cinders, or mixture of any of these aggregates with aggregates for Grade A Concrete.
18. Grade C Concrete is any concrete not classed as Grade A or Grade B. (Siliceous gravels such as quartz and chert are included in this group.)
19. Ratings given in BMS 92 are based on "x" dimensions (outside protection) of 2, 3 and 4 inches, for four classes of concrete aggregate. These ratings vary from 1¾ hours to 14 hours. Because these tested ratings are of limited practical value to the designer, most building code officials have adopted modified rating schedules interpolated from actual test data. Ratings No. 23, 24, and 25 in this appendix are the ratings adopted by the Uniform Building Code. Other model codes such as National Building Code and Southern Building Code have similar but different schedules. In general the ratings shown are more conservative than those of other model codes, except that the Southern Building Code requires heavier protections when concrete fireproofing contains siliceous aggregate having a total of more than 60% quartz, chert or flint.
20. Tested with covering of ½" sand-gypsum plaster, for which the rating was 6 hours.
21. Tested with covering of ⅜" sand-gypsum plaster, for which the rating was 7 hours.

22. Retardant 2689-5 rates the vermiculite-gypsum protection at 5 hours. Tests in Retardants 3413-4 and 4197-1 were stopped at 4 hours, before test limits were reached.

23. Rated at 2 hours by Underwriters' Laboratories, Inc., although test results indicate 2½-hour rating.

24. 3.4 lbs. per sq. yd. 24 ga. metal rib lath.

25. In tested constructions beams projected below ceiling line by varying distances, but for convenience the following rule from NBFU "Fire Resistance Ratings" is applied:
"Ratings given are applicable where there is no combustible material or construction in the enclosed ceiling space. Ceiling to be at such a level that the beams, girders or trusses to be considered as protected by the ceiling, will not extend below the level of the ceiling more than 6 inches (as illustrated), unless otherwise specified. This depth at any point to be considered as the average depth on the two sides. Ratings are for protection only from fire beneath the ceiling."

26. Scratch Coat: 1 lb. aggregate to 2 lbs. fibered gypsum.
Brown Coat: 1 lb. aggregate to 3 lbs. fibered gypsum.

27. 1 lb. aggregate to 1 lb. fibered gypsum.

28. 2 lbs. aggregate to 1 lb. fibered gypsum.

29. Scratch Coat: 2 lbs. aggregate to 1 lb. portland cement (with 10 lbs. hydrated lime added per bag of cement.)
Brown Coat: 2½ lbs. aggregate to 1 lb. portland cement (hydrated lime added same as Scratch Coat.)

30. 3 lbs. asbestos fiber and 15 lbs. hydrated lime per 100 lbs. portland cement.

31. Insulation Board: ¾" aluminum foil faced fiber glass weighing 0.5 lbs. per sq. ft., ash content 91% by weight.

32. 6 cu. ft. aggregate to 94 lbs. portland cement.

33. Rated at 1-hour by Underwriters' Laboratories, Inc., although test results indicate 1½-hour rating.

34. 4 cu. ft. of aggregate to 94 lbs. of portland cement.

35. Specified minimum thickness of slab refers to thickness above joists. In tested constructions the thickness between joists was greater due to sagging of the metal lath form. If rigid forms prevent the sagging the slab thickness should be ¼" greater. Concrete plank may be substituted for the poured concrete slab if joints are thoroughly grouted and the plank is ¼" thicker than the specified slab thickness.

36. Wood nailers may be placed in top slabs provided they are separated from the top of the steel joist by the following minimum thickness of concrete or gypsum:

1½-hour Fire-Resistant Construction —	1 inch
2 -hour Fire-Resistant Construction —	1⅛ inch
2½-hour Fire-Resistant Construction —	1⅜ inch
3 -hour Fire-Resistant Construction —	1⅝ inch
4 -hour Fire-Resistant Construction —	1⅝ inch

37. Proprietary roof plank.

38. Tested construction included open-web joists. Main runner support clips were wrapped around lower chord of joist.

39. Retardant 3390-6 lists a 6" thick siliceous gravel slab with 1" covering as achieving a 3-hour rating. This discrepancy may be due to differences in quality of the siliceous aggregate.

40. Retardant 3390-8 lists a 4¾" siliceous gravel slab with 1" covering as achieving a 2-hour rating. This discrepancy may be due to differences in the quality of the siliceous aggregate.

41. Portions of slab not containing electrical raceways and junction boxes may consist of a 3" slab.

42. Portions of slab not containing electrical raceways and junction boxes may consist of a 2" slab.

District Engineer Offices

ATLANTA, GEORGIA 333 Candler Building

BIRMINGHAM, ALABAMA 407 Frank Nelson Building

BOSTON, MASSACHUSETTS 11 Beacon Street

CHICAGO, ILLINOIS 53 West Jackson Boulevard

DALLAS, TEXAS 1316 Davis Building

DETROIT, MICHIGAN 810 Mutual Building

GREENSBORO, NORTH CAROLINA Watson Building

LOS ANGELES, CALIFORNIA 714 West Olympic Boulevard

MILWAUKEE, WISCONSIN 7616 Harwood Avenue

MINNEAPOLIS, MINNESOTA 2507 Foshay Tower

NEW YORK, NEW YORK 101 Park Avenue

OKLAHOMA CITY, OKLAHOMA 2309 Liberty Bank Building

OMAHA, NEBRASKA 826 City National Bank Building

PHILADELPHIA, PENNSYLVANIA 1617 Pennsylvania Boulevard

PITTSBURGH, PENNSYLVANIA 981-B Union Trust Building

SAN FRANCISCO, CALIFORNIA 420 Market Street

SEATTLE, WASHINGTON 777 Dexter Horton Building

ST. LOUIS, MISSOURI 18 Olive Street

SYRACUSE, NEW YORK 410 Marine Midland Building

Executive Offices

NEW YORK, NEW YORK 101 Park Avenue

THE AMERICAN INSTITUTE OF STEEL CONSTRUCTION, INC.